WATER & WASTEWATER ENERGY MANAGEMENT

Best Practices Handbook

Hawaii Edition

Hawaii Energy
YOUR CONSERVATION & EFFICIENCY PROGRAM

April 2014

Water & Wastewater Energy Management Best Practice Handbook

Presented by:

Hawaii Energy
YOUR CONSERVATION & EFFICIENCY PROGRAM

Developed by:

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An electronic version of this handbook is available at www.hawaiienergy.com/additional-resources.
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Images and photos in this handbook were developed by Leidos Engineering, LLC, unless otherwise noted.

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Special Message from Governor Neil Abercrombie

In recent years, it has become clear to all who live in Hawaii that there is a direct and important connection between water and energy usage. Both are inseparably linked in ways that affect our environment, impact our pocketbooks, and influence the economic sustainability of our islands. This is mainly due to the significant energy that is required to operate water and wastewater facilities. The resulting costs from this water-energy nexus are aggravated by the continuing increase in electricity rates as oil prices continue to rise. As a result, water and wastewater facilities face very difficult challenges in controlling operating costs and, ultimately, costs to their customers.

In an effort to address these challenges, this Administration, through the Hawaii Public Utilities Commission (PUC), has directed Hawaii Energy, the state's energy conservation and efficiency program, to develop energy-saving strategies and programs specifically focused on providing efficiency incentives, training and education across the full spectrum of water/wastewater operations and customer usage. While water quality and public safety will always be the first priority of water and wastewater operations, improved energy efficiency and conservation can ensure that we continue to provide these vital services at an affordable cost to all Hawaii citizens while also achieving the state's clean energy goals.

This manual is developed uniquely for Hawaii and is one of several actions that Hawaii Energy has initiated to carry out this directive. It provides information and guidance to all levels within the water and wastewater industry, from leadership to operations personnel.

I encourage the use of this manual by those in the water and wastewater treatment industry who are involved in capital projects, maintenance and repair, or operational decision-making. These services and resources from Hawaii Energy help to bring the best-in-class energy-saving information and techniques in the water/wastewater industry to all water and wastewater operations throughout the Hawaiian Islands, including consumers. This manual is a valuable resource for our state as well as a practical cost-saving toolkit for the water/wastewater industry.

Additional copies of this manual may be obtained from the Hawaii Energy office or downloaded online at www.HawaiiEnergy.com/water-and-wastewater.

Mahalo for your interest and support for a more energy-efficient and sustainable Hawaii.

With warmest regards,

Neil Abercrombie

NEIL ABERCROMBIE
Governor, State of Hawai‘i

1. INTRODUCTION

Hawaii Energy is a ratepayer-funded energy conservation and efficiency program administered by Leidos Engineering, LLC under contract with the Hawaii Public Utilities Commission serving the islands of Hawaii, Lanai, Maui, Molokai and Oahu. In its current form, Hawaii Energy is funded through the Public Benefits Fund (PBF) and is charged with supporting Hawaii's Energy Efficiency Portfolio Standards (EEPS). Hawaii Energy strives to:

- be the best steward of ratepayer's funds and return maximum energy efficiency for each dollar spent;
- use innovation and technology to reduce Hawaii's dependence on imported oil for producing electricity;
- support all PBF ratepayers and encourage maximum participation in energy efficiency and conservation incentive programs;
- set the standard for transformational change in energy efficiency and conservation in Hawaii;
- with this charge, Hawaii Energy has identified the water and wastewater sectors as targets to strategically reduce energy consumption in Hawaii.

1.1 Background

The primary goal of the water and wastewater industry has been to meet regulatory requirements for the protection of human health and the environment. The wastewater sector has focused on maintaining compliance with discharge permit requirements regulated by the U.S. Environmental Protection Agency (EPA) through the Hawaii State Department of Health (HI DOH), while the water treatment sector has focused on requirements as established by the Hawaii State Department of Health, Safe Drinking Water Branch (DOH, SDWB). These regulations are very important and must be adhered to so this practice is vital and necessary. Historically, to ensure achievement of this primary objective, many facilities within the water and wastewater sectors were not designed or operated with a goal of managing energy consumption. The purpose of this manual is to provide operators and managers with proven practices that will allow them to operate their treatment facilities more efficiently while continuing to meet all of the human health and environmental requirements.

A secondary goal of the water and wastewater industry is to provide its services for reasonable and fair user fees or rates. These fees are typically developed based on the debt service for capital improvements, operating expenses (labor, energy, chemical, etc.) and reserve accounts. Until recently, many water and wastewater utilities treated energy costs simply as a cost of doing business, without significant efforts to manage consumption. As a result, capital reserves were often depleted to offset rising operating expenses in an effort to maintain stable user fees. Funding operations in this manner leaves the utility vulnerable to unforeseen capital expenditures and may result in inadequate investment in the maintenance, repair and upgrade of process equipment and facilities; or may cause utilities to base all equipment purchases solely on initial capital cost, rather than considering the life-cycle cost of owning and operating the equipment. This manual provides information and examples of life-cycle cost analysis that, when applied to upgrade or retrofit project cost analysis, gives industry leaders the full cost and benefit of such projects resulting in more informed decision making.

1.2 Description

In Hawaii, municipal and private regulated water and wastewater utilities provide services to over 95 percent of the state's population. According to State Department of Health records, the wastewater sector includes 206 regulated wastewater treatment facilities (WWTFs) with a combined design treatment capacity of more than 243 million gallons per day (MGD) and an average daily flow of 121 million gallons. The drinking water sector includes 130 regulated public water supply systems, consisting of surface and ground water sources, producing approximately 260 million gallons per day of drinking water (State of Hawaii Annual Public Water System Compliance Report, 2010).

Hawaii Energy conducted a statewide survey of the State's municipal water and wastewater systems' energy consumption in 2013. Based on this survey, it was estimated that energy use by the municipal water and wastewater sectors is approximately 290.3 million kilowatt hours per year and 56,422 kW, about 3.2% of the Hawaiian Electric Companies' total sales for the same period. The survey also revealed that the water and wastewater systems do not currently have sufficient energy data to accurately benchmark at the treatment plant/pumping station level. Hawaii Energy will sponsor a benchmarking program beginning in July 2014 to provide this much needed data.

It is generally accepted that 20% or more energy savings can be gained from energy efficiency measures in the water and wastewater sectors. For Hawaii, the savings could be more than 58 million kilowatt hours per year or $16.1 million dollars, based on January 2014 energy and demand charges.

1.3 Purpose

As stated previously, the water and wastewater industry's primary objectives are meeting environmental and other regulatory requirements and protecting public health and welfare. These objectives cannot be understated and must always be the industry's top priority. Nevertheless, with continually rising energy costs, a greater financial burden is being placed on local governments, industrial companies and ultimately the customers and ratepayers. In addition, when rate increases are requested by the water and wastewater sectors, energy costs are the predominate reason identified for the needed increase. In this context, water and wastewater system managers must make capital and operational decisions with energy consumption as a major consideration.

Energy efficiency and the protection of public health, welfare and the environment can work together. Often, energy efficiency programs go beyond reducing the amount of energy consumed at a facility by improving the control and operation of unit treatment processes – ensuring the facilities meet or exceed their permit requirements while reducing the amount of energy required to do so.

The purpose of this Water & Wastewater Energy Management Best Practices Handbook is to provide a resource to the water and wastewater industry that can be used in the development of an energy management program, the implementation of capital and operational improvements that reduce energy consumption and to show how to track performance and assess program effectiveness. It is meant to be a practical guide that can be used at all levels of the industry's management team to assist in making informed decisions in all aspects of facility operations, repair and investment.

2. ENERGY MANAGEMENT PROGRAM DEVELOPMENT

Energy management planning goes beyond lowering on-peak demands and improving energy efficiency. Most water and wastewater utilities should incorporate a broad range of energy management goals including:

- improving energy efficiency & managing total energy consumption;
- controlling on-peak demand;
- managing energy cost volatility;
- improving energy reliability;
- improving the effectiveness of operations;
- minimizing fee/rate impacts;
- assessing the opportunity for energy neutrality.

Water and wastewater utilities are tasked with the mission of minimizing the costs associated with protecting water resources while maintaining a high degree of reliability. The goals listed above consider both the costs associated with energy consumption and reliability of energy over time. A good energy management plan needs to balance these goals to avoid unanticipated costs and still exploit all of the available energy efficiency and renewable energy opportunities.

2.1 Understanding Energy Management Goals

The goals of an energy management program can often overlap with other utility best management practices. For example, an effective preventive maintenance program can improve motor efficiency and system reliability. Similarly, improvements to the overall efficiency of water and wastewater treatment will improve energy performance as measured by energy benchmarks, such as gallons of water sold or treated per kilowatt hour of electricity consumed. Results can be shown from improvements such as leak detection and repairs to the water distribution system, or from reducing infiltration and inflow to wastewater collection systems.

Implementation of energy management practices can also have ancillary effects, such as: improved treatment, lower maintenance, increased equipment life, reduction in chemical consumption, reduced surcharges improvement in staff communications and morale and a better understanding of the treatment processes. These ancillary benefits of energy management should also be considered when evaluating prospective energy management opportunities.

Water and wastewater treatment is intrinsically energy intensive due mainly to the need to move large volumes of water using pumps and electric motors. The cost of the electricity used in treatment processes is based on two main components: the quantity and demand level of electricity used.

2.2 Basic Steps Involved in Building an Energy Management Program

The following section outlines a multi-step approach to developing an effective energy management program. The ten steps are as follows:

Step 1	Establish Organizational Commitment
Step 2	Assemble an Energy Team
Step 3	Develop a Baseline of Energy Use
Step 4	Evaluate the Water/Wastewater System and Collect Data
Step 5	Identify Energy Efficiency Opportunities
Step 6	Assess Renewable Energy Opportunities
Step 7	Prioritize Opportunities for Implementation
Step 8	Develop an Implementation Plan
Step 9	Track and Report Progress
Step 10	Continually Update Plan To Achieve Energy Neutrality

The primary goal of this approach is to ensure that energy-related decisions are fully documented, analyzed and implemented and that all stakeholders understand the reasoning behind any proposed energy efficiency or renewable energy projects.

Step 1 of the energy management program approach acknowledges the need to obtain management commitment and support. In addition to sanctioning the formation of an energy team in Step 2, this step ensures that projects will be able to advance to implementation.

Step 2 of the approach focuses on building a diverse energy team, represented by key stakeholders that are committed to supporting the energy management process over the long term. Energy use cuts across many organizational boundaries, so it is important to have a diverse team to understand the wide variety of issues and needs associated with energy use. The specific level of effort required from different team members may vary throughout the process, but it is essential to maintain involvement and commitment.

Step 3 encompasses the gathering of data that will provide an energy baseline that will enable a comparison with future energy use, after improvements have been completed. The data gathered should be relatively easy to collect and available, such as that obtained from metering and should be time-labeled. Baseline data should include production data, such as MGD or amount of BOD treated, along with the corresponding demand and energy usage. The index of performance (key performance indicator - KPI) will be in kilowatt-hours per unit of flow (or something similar). The time that an intervention is made, such as the installation of new equipment, should be recorded on the timeline of the tracked data so that the impact of the intervention can be seen as a reduction in KPI. It may even be worth gathering data on specific large units of equipment, such as pumps or aerators.

Step 4 focuses on building a strong understanding of existing energy use and costs. Reviewing and understanding the electric bill is critical in accomplishing this step of the process. *Appendix A* explains a typical utility bill for a wastewater treatment facility in Hawaii. The facility manager should know which end users in the operation consume the most energy. A profile of energy use, with respect to end use should be developed. A typical distribution of energy use per process can be seen in *Appendix B*.

Steps 5, 6 and 7 focus on utilizing the data profile to identify energy efficiency and renewable energy opportunities and prioritizing them in the context of the overall business and regulatory priorities of the facility. If the expertise to analyze the opportunities does not exist in-house, consider hiring an external expert who can develop a list of priorities and a plan.

Steps 8 and 9 ensure that the implementation plan is effectively executed and that energy savings resulting from the installed measures are realized. Results are tracked and reported to management so the impact of the effort can be understood.

Step 10 reinforces continual improvement of the process by finding and refining new project opportunities and adjusting the implementation plan according to changing needs. This step also recognizes the ideal end-state in which energy neutrality is achieved. While this goal may not be achievable by every water or wastewater system, many systems can get near the end-state.

Most options for changing energy use involve some commitment of resources, typically a capital investment or a modification to standard operating procedures. Trade-offs among various values can make investment decisions difficult, underscoring the need for a diverse, representative energy team. Specifically, a diverse energy management team can evaluate the trade-offs from a variety of perspectives so representatives with different responsibilities can ensure that none of the utility's primary goals are compromised by the proposed changes. Good quality energy use information allows the team to evaluate the benefits and costs, tangible and intangible and illuminate the decision-making process.

When pursuing the goal of energy efficiency, it is necessary to continually monitor and assess where additional energy efficiency can be obtained. Energy management is a continuous effort, requiring continuous support, to assure that facility projects are energy-efficient. As changes to effluent requirements recur, facility managers must continually be vigilant in addressing energy efficiency opportunities to be sure that the least amount of energy is being used to meet permitted effluent limits.

Each of the ten steps is described in more detail below.

2.2.1 Step 1: Establish Organizational Commitment

Successful energy management requires a focused, coordinated and empowered effort. Effective energy management begins at the top and requires a champion who will put the full force of the organization behind an energy team's decisions. All power must flow from management into an energy management team charged with achieving energy efficiency goals.

2.2.2 Step 2: Assemble an Energy Team

Municipalities and industries should assemble an energy team that represents as many stakeholders as possible, including management, administration, accounting, compliance, operation and maintenance. The integration of all of the disciplines into the team spreads the responsibility of achieving energy management goals.

The team needs to seek and maintain support of management so it can continue to be empowered to implement the actions necessary to guide the water/wastewater system toward energy efficiency and sustainability.

The team is responsible for profiling energy use, identifying and evaluating all energy efficiency opportunities, establishing attainable energy goals, prioritizing and selecting projects, commandeering the resources necessary to make each project successful and making sure the impacts are measured and reported to management.

A strong energy team, backed by a commitment from utility management, will help to resolve many of the organizational barriers to improving energy use. For example, in some utilities the operations staff is never involved in evaluating energy procurement decisions and may never see energy bills. In an effective energy management model, a cross-functional energy team helps to improve communications between the business group and the operations staff, reinforcing the connection between energy use and energy procurement. For example, an energy team could include an elected official, such as the Town Engineer or the Mayor, a manager at the treatment plant, an operator and a member of the finance department. In cases where changes to energy management practices will result in facility design modifications, the appropriate regulatory agency could also be invited.

An effective energy team will:

- **Develop a Strategic Energy Management Plan.** This plan should establish the overall mission and document the organization's commitment to achieving energy efficiency goals.

- **Establish performance goals, metrics and incentives.** This task includes establishing benchmarks, targets, ways to measure changes in performance indicators and ways to encourage support of these efforts. This also includes establishing a communications plan, showing how information will be shared, assigning tasks and setting a schedule of milestones and deadlines.

- **Define resource needs.** Utility management should demonstrate a commitment to the program by allocating resources to achieve the stated goals. The team will be responsible for identifying resource needs such as staff time, equipment, external consulting support and budget. Resource requests should be balanced by projected energy use reductions.

- **Serve as an energy information clearinghouse.** The energy team should be a utility-wide resource that provides information about energy use and coordinates communications about any projects that impact energy use. For example, recommendations from the energy management team should be coordinated with the capital improvement planning process and annual maintenance program.

Keys to success:

- Management must support and participate on the energy team.
- The energy team should be cross-functional.
- Resources need to be allocated to team activities and to energy efficiency projects.
- Progress along key performance indicators showing progress toward energy goals should be shared with all employees of the utility, including management and administration.

2.2.3 Step 3: Develop a Baseline of Energy Use

At a minimum, improving a specific water/wastewater systems understanding of where, why and when energy is used should be one of the primary goals of the energy team and a required objective of the Strategic Energy Management Plan (SEMP). Some studies have demonstrated that even the process of investigating energy use and improving awareness among staff, can provide measurable energy efficiency savings ranging from three percent to five percent. This step focuses on gathering readily available energy use information and organizing that information into a basic 'model' that can help to understand energy use patterns and communicate initial findings. The model can be as simple as listing all of the major energy using processes, obtaining a power draw for each specific process and based on the times of operation, estimate both process and system energy use, including off-peak and on-peak.

The typical tasks of this step are to:

- Collect and organize equipment, energy use, hydraulic and organic loading data.
- Develop an understanding of where, why and when energy is used.
- Understand energy bills and the rate structure that is used to set energy costs.
- Create a baseline of energy use and performance metrics to be used for comparison and evaluation purposes, based on energy use per unit of output.

Specific actions needed to formulate a baseline include:

- **Gathering basic billing information.** One year of data should be analyzed at a minimum to identify any seasonal patterns, but three or more years of data is ideal, so that any trends and anomalies can be found. Data sources can include utility billing records, supervisory control and data acquisition (SCADA) system records, O&M records and equipment/motor lists with horsepower and load information. Regulatory agency water quality reporting records providing hydraulic and waste strength characteristics may also be important.
- **Organizing treatment processes by functional area.** Identifying logical functional groups makes performance measurement and benchmarking easier and will also facilitate planning for separating energy loads to better manage demand.
- **Evaluating energy bills and understanding the energy rate structure.** Many energy management strategies are directly linked to the pricing of energy and it is critical to understand how the 'energy rate structure' affects energy costs and which particular rate structure applies to your water/wastewater system. It may also be useful to determine what other options are available. Reaching out directly to the power utility account manager for additional assistance in understanding rate structures available to your system can also help.
- **Assessing the relationships between changes in hydraulic loading, organic loading and energy use.** Hydraulic data (i.e. flow) and organic loadings should be assembled to understand patterns of demand and correlations between flow, organic loading and energy use. Analyze data at several time frames to identify diurnal patterns,

seasonal patterns, correlations between wet and dry weather, average day flows and energy demand.

- **Building a basic 'model' to organize data and capture energy use patterns.** Typical models used in this stage of the process can be created using a generic spreadsheet, or for larger utilities, it may be helpful to purchase specific software for organizing energy data. The level of modeling sophistication can range from a basic motor list relating horsepower to energy demand (kW), to a time-varying (dynamic) model that predicts hourly demand and energy costs. The process of modeling can help to identify what types of information are most helpful, the limitations on currently available information and what data needs to be gathered in the field. In addition, an energy use model can be a valuable tool for testing theories, validating your understanding of energy use, calculating performance metrics and visualizing and communicating energy use patterns.

- **Create basic graphics and reports to communicate initial findings.** Although this is an early step in the process, it can produce some valuable insights that should be shared with a wider audience, including the systems management, administration, operation and maintenance personnel as well as the energy team.

Key to success:

- Building understanding through communication is in an iterative process. Start small and grow the level of complexity of your information- gathering to match your goals, needs and resources. Similarly, you should use your initial findings to organize and justify future and more detailed information-gathering efforts and focus resources accordingly.

2.2.4 Step 4: Evaluate the Water/Wastewater System and Collect Data

Whereas the initial baseline of energy use is developed primarily using historical records, this evaluation step involves collecting new field data to track energy use in the new context of energy management.

One important tool that should be used during this step is interviewing supervisory, operations and maintenance staff. Interviews can help to verify your understanding of energy use, identify limitations to future actions and provide helpful suggestions for energy efficiency opportunities.

The specific actions required in this step include the following:

- **Perform system walk-through.** Verify equipment lists, operating status and motor sizes for major unit treatment systems.

- **Interview staff.** Build understanding of operating practices, maintenance practices and history, regulatory and engineering limitations, operational priorities and collect suggestions for energy efficiency project opportunities.

- **Gather energy performance data.** Fill gaps in the energy model with field data. This may include direct measurements using a power meter, tracking average equipment run times of motors throughout the day, or using a more sophisticated submetering system to gather actual energy use and time of use data.

- **Track energy performance.** Apply the data collected for measuring key performance indicators as developed in **Step 3.** Examples include: kWh per million gallons treated (kWh/MG), comparison of peak demand (kW) with peak pumping rates (gpm) and before and after measurements of energy use and contaminant removal, such as kWh/lb of BOD removed. Performance metrics can be compared with historical data or engineering design criteria, or can be used for external benchmarking in comparison to similar facilities.

- **Update the energy use model.** Make any improvements and/or corrections in the energy use model using newly gathered field data and observations. This may include refining assumptions such as the loadings or times of use for various motors.

Key to success:

- Apply energy baseline results (**Step 3**) to prioritize field efforts on the most promising areas. Typically the larger motors and energy intensive processes are good initial candidates. It may be necessary or economical to collect field data for the largest equipment only. Approximations may be an acceptable alternative to field data for smaller systems and motors.

2.2.5 Step 5: Identify Energy Efficiency Opportunities

Energy efficiency opportunities can be any system change (equipment or operations) that reduces energy consumption or demand. At this stage, the energy team should identify a broad array of energy efficiency opportunities with the understanding that the next step of the process will focus on identifying and evaluating the best opportunities. Ideas for energy efficiency opportunities can come from a variety of sources, including reference materials, success stories from similar water/wastewater systems, interviews with staff, consultant recommendations, or discussions with energy providers or energy efficiency program advisors. Categorizing energy efficiency opportunities can help to organize a large amount of information into a manageable format. For example, energy efficiency opportunities can be grouped by process area, or by the funding approach, such as:

- Capital program or equipment replacement
- Process change
- Operational change
- Automation or controls

- Maintenance improvements
- Business case analysis results

The specific actions that will help this step include the following:

- listing and categorizing best practice opportunities, focusing on large equipment and processes where the greatest savings opportunities exist;
- research similar opportunities implemented at other facilities;
- discuss energy efficiency opportunities with external experts, such as utility account representatives, energy efficiency program providers and other external consultants);
- rank projects based on business case analysis results (payback, life cycle cost, ROI, etc.).

Keys to success:

- Consider all stated energy goals.
- Include a wide array of energy efficiency opportunities, but initially focus efforts towards the larger systems.

2.2.6 Step 6: Identify Renewable Energy Opportunities

Apply the same process in identifying and categorizing renewable energy opportunities as described in **Step 5**.

2.2.7 Step 7: Prioritize Opportunities for Implementation

The final product of this step is a short list of energy efficiency and renewable energy opportunities that have been selected and carefully evaluated for energy savings benefits from the list of opportunities generated in **Steps 5 and 6.** This short list of prioritized energy projects should be based on both the water/wastewater system's business priorities and the ability of the projects to meet the team's stated energy goals. As investigated and evaluated by the multi-disciplinary energy team, the listed projects must be economically viable and able to be implemented with minimum risk or conflict.

The difficulty of prioritizing energy efficiency opportunities comes in comparing the goals and risks of different, competing projects. The energy team is responsible for making the various benefit and cost trade-offs and making sense of a properly vetted energy plan. Whenever possible, a benefit-cost test should be used as a criterion for comparing and prioritizing projects. The water/wastewater system will also apply some type of economic evaluation method, such as payback, return on investment, or lifecycle costing to prioritize energy efficiency. A discussion and examples of these economic evaluation methods can be seen in *Appendix C*.

Any complete evaluation of options must also consider intangible effects, such as risk to compliance or the impact on health and safety of workers. Assigning a dollar value to benefits such as reducing the risk of process failure, or improving operator safety, can be challenging. In such cases, it may be necessary to develop more specialized evaluation criteria.

The specific actions required in this step include the following:

- **Identify suitable evaluation criteria for the non-monetary features of energy efficiency opportunities.** Identify those costs and benefits of energy efficiency opportunities that cannot be easily quantified in monetary terms and define appropriate evaluation criteria for those situations.
- **Compare the costs and benefits of the non-monetary features of energy efficiency opportunities.** Score and rank the costs and benefits and organize the evaluation into a table or matrix to communicate results.
- **Evaluate the monetary characteristics of energy efficiency opportunities.** Choose appropriate evaluation methods, quantify costs and benefits, convert all costs into equivalent terms and tally the results.
- **Combine non-monetary and monetary characteristics and rank energy efficiency opportunities.**

Keys to success:

- Convert all criteria used to make comparisons into monetary terms whenever possible. Monetary comparisons are easy to compare and communicate.
- Evaluate all energy efficiency goals, including ancillary benefits whenever possible.
- Make sure that the final results make sense with respect to the utility's overall capabilities and mission. Implementing the energy efficiency opportunities also should not undermine a utility's capacity to implement necessary changes.

2.2.8 Step 8: Develop an Implementation Plan

The previous three steps helped to identify and prioritize energy project opportunities. This step focuses on implementation. The purpose of this step is similar to a business plan in that it should communicate to potential stakeholders exactly what you expect to do, what resources are needed and what outcomes will result from the implementation of projects.

The specific actions required in this step include the following:

- List the energy project opportunities chosen for implementation and describe the goals and objectives of each.
- Indicate the resources needed, including a budget and financing plan.
- Develop and procure any specifications needed, including design criteria and procurement related documents.
- Identify any perceived changes in standard operating procedures and/or process control strategies.
- Develop a schedule for implementation, including milestones and the procurement of the necessary regulatory approvals (if applicable).
- Set realistic expectations for the project(s) in terms of resources required, schedule, procurement time frame and expected energy impacts.

2.2.9 Step 9: Track and Report Progress

The success of a project should be measured beginning with installation. Measurements should focus on key performance metrics, including the status of the schedule, impacts on operations and maintenance, process, performance, staff attitudes and productivity. Results of performance monitoring should be communicated to stakeholders, including anyone involved in the planning process, the O&M staff responsible for implementation and utility management.

This step is often overlooked, even though it is critical to creating a sustainable energy management program for the following reasons:

1. Progress tracking provides insight into making adjustments that can improve the chances of success.
2. Project reporting provides guidance for future decision-making and can help to refine planning assumptions.
3. Reporting project results, especially successes, gives useful feedback to planning and implementation staff, helping to keep them motivated to achieve energy efficiency.

The specific actions required in this step include:

- Assigning responsibility and allocating resources for tracking and reporting the progress of a project.
- Establishing the appropriate performance metrics.
- Creating the communication plan that pinpoints what should be reported, who progress reports are delivered to (such as elected officials or the public), when they should be delivered and any follow-up actions that may be required.

Keys to success:

- Performance metrics should focus on the impacts of the energy efficiency project.
- Reporting should generate some follow-up activities to demonstrate a commitment to the project.

2.2.10 Step 10: Continually Update Plan To Achieve Energy Neutrality

The previous steps have presented how to develop an energy team, develop your energy baseline, identify energy efficiency projects, implement energy efficiency projects, and measure and promote their value. This step is a reminder that energy efficiency is not a one-time action but needs to be continuous and ever-changing so energy efficiency becomes a seamless part of the business process of the utility. The water/wastewater industry in general should continue to move forward in its quest to implement energy efficiency and renewable energy, both in retrofits and in new designs.

Generally, a water/wastewater system will focus its first efforts on becoming as energy-efficient as is practicable, making sure that all of its processes and end uses are as "trim" as possible. Placing emphasis on energy efficiency before renewable energy projects is usually the most logical approach. When a water/wastewater system's energy usage footprint is minimized, it becomes easiest to meet the remaining energy needs with internally-generated renewable energy resources.

Once energy efficiency is achieved, the next steps are to assess the applicability of renewable energy resource options. A variety of renewable sources are available: solar, wind, hydro and biogas, among others. Each source needs to be reviewed and assessed, site-specifically, for its feasibility and its lifecycle cost. It may even be that a combination of renewable resources is appropriate for a site. For example, a combination of solar and biogas may be appropriate. A solar system can offset some energy requirements during the daylight hours and a biogas system can offset the energy requirements during the evening hours or during cloudy days. Each site should be assessed for which potential would best fit its requirements.

The goal of attaining energy neutrality should be incorporated into any energy plan. Water/wastewater systems that are moving forward and becoming energy-efficient are realizing there are a variety of options available for them to become energy neutral. Typically, this is a combination of energy efficiency and the use of self-generated renewable energy.

2.3 Constraints to Implementing an Energy Program

Most engineering decisions have to be made within the context of trade-offs, or counterbalancing constraints. Awareness and understanding of constraints is a requirement for good energy planning and decision making.

Typical constraints on energy projects include the following:

- Organizational constraints
- Capital costs
- Process reliability
- Acceptance of modifications by facility personnel
- Regulatory requirements, approvals and limits
- O&M capabilities and non-energy O&M costs
- Engineering feasibility
- Space availability

While energy efficiency remains a very important goal, it should not undermine design limitations or compliance with regulatory requirements. Site characteristics and all of the variables that influence project selection (labor, chemical costs, disposal costs, capital costs, etc.) may render even the most energy-efficient solution undesirable.

3. ENERGY MANAGEMENT BEST PRACTICES

This section provides a collection of energy management best practices that are provided as a reference to develop an effective energy management program, identify "low-hanging fruit" and make energy conservation, energy efficiency and energy management a cultural change. The energy management best practices are provided as technical guidance for facility personnel, engineers and/or regulators to consider energy conservation, efficiency and management in design and operation of systems and equipment. They provide technical guidance on specific processes and equipment that are grouped into the following categories:

- General Energy Management Best Practices
- Water Energy Management Best Practices
- Wastewater Energy Management Best Practices
- Building Systems Energy Management Best Practices

General Energy Management Best Practices include design or operation practices that are applicable to both water supply and distribution systems and wastewater treatment and collection systems. This section also provides greater detail for approaches to develop energy management plans and manage electric bills as discussed in the previous section. Most opportunities for energy efficiency improvements in both water and wastewater systems can be found in electric motors and the use of controls to optimize operation according to variable conditions. Best practices for reducing electric use in pumps, filtration and disinfection systems are included in this section.

Water Management Best Practices include design or operation practices that are applicable to water supply and distribution systems. Regardless of whether a water system relies on a surface water supply or a ground-water supply, the majority (over 90%) of energy use is related to pumping, whether it is process pumping or backwash pumping. Opportunities for energy efficiency improvements in water supply and distribution systems can be found in optimization of pump and well operations and in reduction of the volume of water being treated and distributed.

Wastewater Energy Management Best Practices include design or operation practices that are applicable to wastewater treatment and collection systems. The majority of electricity use in the wastewater sector occurs at the wastewater treatment facilities (WWTFs). Nevertheless, electricity is consumed at pumping stations within the collection system as well. In WWTFs, over two-thirds of overall energy consumption is in secondary treatment processes. These processes usually represent the greatest opportunity for energy savings. Other components that offer opportunities for energy efficiency improvements are the solids handling processes and disinfection systems (UV systems). One unique aspect of the wastewater sector is the potential for on-site electrical and thermal energy generation using anaerobic digester gas, a byproduct of the anaerobic sludge digestion process, as a renewable energy resource.

Building Systems Energy Management Best Practices include design or operation practices that are applicable to energy management in water and wastewater building systems. HVAC and lighting systems generally provide the highest opportunities for energy-efficient improvements. The Leadership in Energy and Environmental Design (LEED) program focuses on the efficiency of building systems.

3.1. How To Use This Handbook

The Energy Management Best Practices are sequentially numbered for easier consultation and presented in a one to two-page format. Each best practice is designed to stand alone, so you can either: 1) go through each one, starting with the first and working your way through until you have covered the whole facility, or 2) search only for practices applicable to your facility. Best Practices that support, or are supported by other processes are referenced under "See Also". More information can be found on the Hawaii Energy website at www.hawaiienergy.com/water-and-wastewater.

Whether you are consulting this handbook in search of tips on how to operate your facility in a more energy-efficient manner, looking for estimated savings and payback for a capital project, or are designing a new facility or single process equipment, we hope that you find this handbook useful. Please feel free to send comments or suggestions to improve this handbook to hawaiienergy@leidos.com.

Photo courtesy of Maui Department of Water Supply

3.2. Best Practices Summary

General Best Practices

G1 – Facility Energy Assessments

G2 – Real-Time Energy Monitoring

G3 – Energy Education for Facility Personnel

G4 – Comprehensive Planning Before Design

G5 – Design Flexibility for Today and Tomorrow

G6 – Electric Peak Reduction

G7 – Manage Electric Rate Structure

G8 – Idle or Turn Off Equipment

G9 – Electric Motors: Install High-Efficiency Motors

G10 – Electric Motors: Automate to Monitor and Control

G11 – Supervisory Control and Data Acquisition (SCADA)

G12 – Electric Motors: Variable Frequency Drive Applications

G13 – Electric Motors: Correctly Size Motors

G14 – Electric Motors: Properly Maintain Motors

G15 – Electric Motors: Improve Power Factor

G16 – Pumps: Optimize Pump System Efficiency

G17 – Pumps: Reduce Pumping Flow

G18 – Pumps: Reduce Pumping Head

G19 – Pumps: Avoid Pump Discharge Throttling

G20 – Filtration: Sequence Backwash Cycles

G21 – Ultraviolet (UV) Disinfection Options

G22 – Energy Manager

G23 – Utilize and Manage Monitored and Recorded Data

G24 – Ensure Plant Personnel Receive, Review and Understand Monthly Energy Bills

G25 – Utilize Life-Cycle Cost Analysis for Purchase Selection

G26 – Energy Efficiency Projects Can Pay for Themselves

G27 – How Do I Implement Energy Efficiency and/or Renewable Energy Projects

G28 – Pump Station Assessment

Water Best Practices

W1 – Integrate System Demand and Power Demand

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W3 – System Leak Detection and Repair

W4 – Manage Well Production and Draw Down

W5 – Sequence Well Operation

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W8 – Sprinkling Reduction Program

W9 – Manage High Volume Users

W10 – Energy-Efficient Membrane Treatment

Wastewater Best Practices

WW1 – Operational Flexibility

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WW4 – Flexible Sequencing of Basin Use

WW5 – Optimize Aeration System

WW6 – Fine Bubble Aeration

WW7 – Variable Blower Air Flow Rate

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WW11 – Sludge: Replace Centrifuge with Screw Press

WW12 – Sludge: Replace Centrifuge with Gravity Belt Thickener

WW13 – Biosolids Digestion Options

WW14 – Aerobic Digestion Options

WW15 – Biosolids Mixing Options in Aerobic Digesters

WW16 – Biosolids Mixing Options in Anaerobic Digesters

WW17 – Optimize Anaerobic Digester Performance

WW18 – Use Biogas to Produce Heat and/or Power

WW19 – Cover Basins to Reduce Aerosol and Odor Emissions

WW20 – Reduce Fresh Water Consumption/Final Effluent Recycling

WW21 – Anoxic Zone Mixing Options

WW22 – Biogas: Beneficial Utilization

WW23 – Biotower Energy Efficiency

WW24 – Energy-Efficient Membrane Treatment Options

WW25 – Blower Technology Options

Buildings Best Practices

B1 – Install VFD Control on Air Compressors

B2 – Install High-Efficiency Lighting and Advanced Controls

B3 – Clean Lamps and Fixtures

B4 – Monitor Light Operation

B5 – Check Outside Air Ventialtion Devices, Ventilation/Supply Fans and Clean Fan Blades

B6 – Replace Ventilation Air Filters

B7 – LEED Energy Practice

B8 – Evaluate Existing Heating, Ventilatin and Air Conditioning (HVAC) for Re-comissioning or Replacement

Best Practices are reprinted or modified from the Water and Wastewater Energy Best Practice Guidebook provided by Focus on Energy, prepared by Science Applications International Corporation (SAIC), December 2006, with authorization.

GENERAL BEST PRACTICES

Checklist for General Best Practices

Best Practice Analyzed? (Date)	Further Review Needed? (Yes/No)	Best Practice Possible? (Yes/No)	#	Best Practice	Typical Energy Savings of Unit Process (%)	Typical Payback (years)
			1	Facility Energy Assessments	10 – 50	Variable
			2	Real-Time Energy Monitoring	5 – 20	Variable
			3	Energy Education for Facility Personnel	Variable	Variable
			4	Comprehensive Planning Before Design	Variable	0.5 - 5
			5	Design Flexibility for Today and Tomorrow	Variable	1 - 5
			6	Electric Peak Reduction	Variable	< 1
			7	Manage Electric Rate Structure	Variable	Variable
			8	Idle or Turn Off Equipment	Variable	< 1
			9	Electric Motors: Install High Efficiency Motors	5 – 10	< 2
			10	Electric Motors: Automate to Monitor and Control	Variable	Variable
			11	Supervisory Control and Data Acquisition (SCADA)	Variable	Variable
			12	Electric Motors: Variable Frequency Drive Applications	10 – 40	0.5 - 5
			13	Electric Motors: Correctly Size Motors	Variable	Variable
			14	Electric Motors: Properly Maintain Motors	Variable	Variable
			15	Electric Motors: Improve Power Factor	Variable	Variable
			16	Pumps: Optimize Pump System Efficiency	15 – 30	0.25 - 3
			17	Pumps: Reduce Pumping Flow	Variable	Variable
			18	Pumps: Reduce Pumping Head	Variable	Variable
			19	Pumps: Avoid Pump Discharge Throttling	10 – 50	Variable
			20	Filtration: Sequence Backwash Cycles	Variable	Variable
			21	Ultraviolet (UV) Disinfection Options	10 – 50	Variable
			22	Energy Manager	Variable	Variable
			23	Utilize and Manage Monitored and Recorded Data	10 – 20	Variable
			24	Ensure Plant Personnel Receive, Review and Understand Monthly Energy Bills	Variable	Variable
			25	Utilize Life-Cycle Cost Analysis for Purchase Selection	Variable	Variable
			26	Energy Efficiency Projects Can Pay for Themselves	Variable	Variable
			27	How Do I Implement Energy Efficiency and/or Renewable Energy Projects	Variable	Variable
			28	Pump Station Assessment	20 – 50	Variable

NOTES:

G1 – Facility Energy Assessments

Best Practice	An annual energy survey should be a common practice for all water and wastewater systems in identifying and prioritizing all opportunities to improve energy efficiency. While the survey should assess major processes, it should also evaluate baseload end-uses such as light and ventilation processes.
See Also	Not applicable.
Primary Area/Process	This practice should examine the entire facility, emphasizing major processes such as pumping, aeration, disinfection and solids management.
Productivity Impact	Minor disruption of production may occur in order to observe equipment operation during the survey.
Economic Benefit	A survey is conducted to identify opportunities for measures with payback, but it does not provide a payback itself. Payback periods vary with the recommendation.
Energy Savings	A survey only identifies energy savings potential. Measure savings typically range from 10% to 50% of the total system energy consumption and may even reach 65%.
Applications & Limitations	None.
Practical Notes	Energy can be saved at every facility, regardless of treatment process, age or facility size, making a survey worthwhile.
Other Benefits	More attention to operations through a survey leads to greater awareness of energy use at all points of operation.
Stage of Acceptance	More facilities are using energy surveys as the starting point for more rigorous energy management.
Resources	The U.S. EPA's tool for benchmarking wastewater and water utilities is a multi-parameter energy performance metric that allows for comparison of energy use among water resource recovery facilities (WRRFs). The tool can be accessed through the U.S. EPA's ENERGY STAR® Portfolio Manager platform (see link below). Portfolio Manager is an interactive energy management web-based system that allows building managers and water/wastewater treatment plant (WWTP) operators to track and assess energy consumption and carbon footprint. The Portfolio Manager is appropriate for primary, secondary and advanced treatment plants with or without nutrient removal. The tool is applicable to WRRFs having design flows of less than 150 MGD. After inputting the following facility information into the Portfolio Manager platform, the tool produces an energy use "score", relative to the scores of a national population of WRRFs, expressed on a scale of 1 to 100. • Average influent flow • Average influent biological oxygen demand (BOD5) • Average effluent biological oxygen demand (BOD5) • Plant design flow rate • Presence of fixed film trickle filtration process • Presence of nutrient removal process The tool is accessed at: http://www.energystar.gov/buildings

G2 – Real-Time Energy Monitoring

Best Practices	An accurate, real-time energy-monitoring system facilitates the collection and analysis of 15-minute energy data for each treatment process and pump system. Monitoring enables utility and management staff to develop energy consumption baselines for various end uses. From established baselines, staff can identify opportunities, set energy reduction goals and monitor/verify results.
See Also	Not applicable.
Primary Area/Process	Monitoring technology can be applied to any process treatment system and is most beneficial for high energy consuming processes, especially for those with variable loads.
Productivity Impact	There is no impact on a facility's capability in meeting production levels or treatment limits.
Economic Benefit	Economic payback depends on the cost of the monitoring system and on the system's ability to help identify savings opportunities. Payback may also be affected if the monitoring equipment can control the system's operating parameters.
Energy Savings	The achievable range of energy savings is typically 5% to 20% at facilities where energy efficiency is viewed as an ongoing function.
Applications & Limitations	Each site must be individually assessed to identify which processes will benefit the most from monitoring.
Practical Notes	The greatest barrier to implementation is acquiring management approval and commitment for the capital expenditure for monitoring equipment. Facility managers should include the potential savings from energy management in the payback calculations needed to justify the investment. This practice has been suggested through benchmark studies.
Other Benefits	Monitoring also can support other functions, such as load management, maintenance and the identification of failing equipment.
Stage of Acceptance	This measure is well known but not widely practiced since it is usually not necessary for meeting system performance goals (effluent limits), nor is it required by design codes.

G3 – Energy Education for Facility Personnel

Best Practice	All water and wastewater system personnel should understand the relationship between energy efficiency and facility operations. Information can be found in various publications, including this handbook and through training sessions offered by organizations (such as Hawaii Energy).
See Also	Not applicable.
Primary Area/Process	This practice focuses on personnel, especially those who make both long- and short-term decisions that affect energy use (including elected officials). All parties involved in the operation of a water treatment and distribution system and a wastewater conveyance and treatment facility can benefit from understanding the system's energy consumption.
Productivity Impact	No impact.
Economic Benefit	There is no direct return on investment for this practice. The return is a function of actual process changes and/or operational changes made in response to recommendations.
Energy Savings	The energy savings for this practice will vary substantially depending on what measures are implemented.
Applications & Limitations	None.
Practical Notes	It is useful to establish an annual schedule for energy training to keep facility management and personnel up-to-date on available technology and management practices.
Other Benefits	Staff members and colleagues within the industry typically share and discuss the information they gain from attending education classes and reading publications.
Stage of Acceptance	Education and training is common and widely accepted throughout the industry.

G4 – Comprehensive Planning Before Design

Best Practice	Incorporate all appropriate energy efficiency best practices into capital and operations improvement plans. Clearly define system goals and objectives and set the design criteria for system improvements. Including energy efficiency up-front in the design stages can avoid lost opportunities once the measure is installed. Correcting a design failure after the fact can be costly.
See Also	Not applicable.
Primary Area/Process	All components of water treatment/distribution and wastewater treatment systems.
Productivity Impact	No impact.
Economic Benefit	Payback will vary by facility size, type of treatment and by project, depending on the energy benefits and costs of alternative designs and operations. Payback may vary from a few months to several years.
Energy Savings	Present and future energy savings are derived from the incorporation of energy efficiency practices in the capital and operations improvement plans.
Applications & Limitations	There are no limitations on this practice because comprehensive planning, including energy-efficient design, occurs prior to project development.
Practical Notes	Proactive and open communications promote the success of capital and operations improvement planning, including energy efficiency and energy management planning. Aggregating energy efficiency measures into a capital improvement project and justifying them in the aggregate, helps avoid lost opportunities for future energy savings. Energy saving improvements should always be evaluated on a life-cycle cost basis.
Other Benefits	Well-conceived and planned projects result in the highest value to the utility.
Stage of Acceptance	Increasingly, utilities are recognizing the value of energy efficiency and management. Its acceptance is growing, especially as a means to better manage limited budgets.

G5 – Design Flexibility for Today and Tomorrow

Best Practice	Operation, administration and management personnel need to be involved with the planning and design of any improvement and/or expansion to their system. Plan design improvements or expansions that have the flexibility to serve both current and future system needs, taking into account any significant anticipated changes.
See Also	Not applicable.
Primary Area/Process	All components of water or wastewater systems.
Productivity Impact	Impact should be negligible.
Economic Benefit	The selected design of any modifications, improvements, or expansions should reflect the highest quality for the most reasonable cost. The simple payback for installing smaller operating units and storage that can manage current system demand, compared with a larger, single unit, operating at reduced capacity, is usually one to five years. Flexible operation that allows for sequencing and incremental load management often has potential for energy savings.
Energy Savings	Energy savings will vary by project, but are directly related to a system's ability to follow demand at all points throughout the system's lifetime, compared with being designed only for 20-year peak flows.
Applications & Limitations	None.
Practical Notes	Begin by conducting an assessment of the size and space needed to install multiple smaller units, as compared to one or two larger units. Note that continuously operating smaller unit(s) will strain the system less than operating a larger unit periodically.
Other Benefits	Having a system that operates effectively and efficiently throughout the life of its design, not just at its future design condition, is a value to the system operations. A flexible operating system will also help manage power demand and avoid unnecessarily high billing peaks.
Stage of Acceptance	Designers and owners are becoming more knowledgeable and accepting of equipment sized to match existing conditions, as opposed to only considering projected peak design needs.

G6 – Electric Peak Reduction

Best Practice	Management of on-peak demand (shifting to off-peak or shaving peak power usage) can substantially lower energy bill costs. The following can be done to optimize power use and reduce electric peak demand: • Assess electric bills to understand on-peak demand charges and examine facility operations to determine ways to avoid or reduce peak demand. • Develop an operation strategy that meets overall system demand and minimizes pumping and specific treatment processes during on-peak power demand periods. Consider adding storage capacity or simply delaying the time of operation. • Assess both the typical and on-peak operations of a water and/or wastewater system to identify areas where on-peak power demand can be trimmed or shifted.
See Also	G7 - Manage Electric Rate Structure G8 - Idle or Turn Off Equipment
Primary Area/Process	All energy-using components of water and wastewater systems, with a focus on the supply side, are candidates for off-peak operation. In wastewater, these include biosolids management (operate sludge presses in off-peak demand times), shifting recycling to off-peak periods, loading or feeding anaerobic digesters off-peak so supernatant does not recycle on-peak, operating mixers or aerators in aerobic digesters off-peak and accepting or treating hauled-in wastes during off-peak. For water systems, pump at rates to meet water demand and not necessarily refilling storage tanks, ensure all storage tanks are full prior to on-peak demand time and consider monitoring on/off levels in storage tanks to reduce energy consumption.
Productivity Impact	No impact.
Economic Benefit	Paybacks are typically less than one year because modifications are generally procedural and not expensive.
Energy Savings	Energy consumption savings (kWh) are generally minor. The majority of savings result from reduced demand for on-peak power.
Applications & Limitations	Application may be limited by the amount of storage available and by the absolute minimum power requirement for necessary operations. Substantial savings are more likely with a time-of-use (TOU) rate. Smaller facilities may not be charged separately for on-peak demand.
Practical Notes	An understanding of the relationship between on-peak power demand and the demands of water supply and wastewater treatment are also necessary to make the application effective.
Other Benefits	Improved use of system components.
Stage of Acceptance	Understanding electric usage helps customers manage their loads according to their specific electric utility rate structures. Most water and wastewater utilities are aware of this, but may not be optimizing operations to fit the rates.

G7 – Manage Electric Rate Structure

Best Practice	Work with the electric utility account manager to review the facility's electric rate structure. The review should determine if the current rate structure is the most appropriate pricing structure for the facility, based on peak demand and overall energy consumption.
See Also	G6 – Electric Peak Reduction.
Primary Area/Process	Facility wide, with special attention to accounting and purchasing.
Productivity Impact	No impact.
Economic Benefit	There is no direct return on investment for this practice. Nevertheless, economic benefit can result from actual process changes made in response to recommendations.
Energy Savings	No direct savings. However, energy and power demand savings may be available if the facility can respond to the current electric rate structure.
Applications & Limitations	All facilities should apply this practice.
Practical Notes	All personnel should be aware of how their specific facility or department is charged for energy consumption and on-peak demand.
Other Benefits	Management will give more attention to the operation of a system if energy awareness is incorporated into daily operating procedures and made available to everyone.
Stage of Acceptance	The practice of reviewing utility bills and rate structures is becoming more common as its value becomes recognized and facilities become more energy cost conscious, especially with respect to how energy costs are incorporated into their water and wastewater treatment rates.

G8 – Idle or Turn Off Equipment

Best Practice	Idle or turn off non-essential equipment when feasible, especially during periods of on-peak power demand. Review operations and operating schedules to determine if any equipment is not required for the proper operation of the facility.
See Also	G6 – Electric Peak Reduction.
Primary Area/Process	This technology can be applied to almost all components in a water or wastewater system.
Productivity Impact	No impact.
Economic Benefit	Paybacks are typically short, if not immediate, because the modifications are low or no-cost changes in operational procedures.
Energy Savings	Savings depend on the amount of non-essential equipment currently operating. Reduced power demand will also result if shut off occurs during periods of on-peak power demand.
Applications & Limitations	Care must be taken not to turn off an essential piece of the treatment process or monitoring equipment or warning system device. Provide as much automatic control, such as timers, as is feasible to reduce the need for operator attention and the potential for operator error. This practice should not undermine compliance with design conditions and regulatory requirements.
Practical Notes	It can be useful to ask why each piece of equipment is operating and if the equipment is critical to the operation of the system. This is of particular value when trying to reduce on-peak power demand charges.
Other Benefits	Increased equipment life, reduced maintenance and possibly fewer spare parts required.
Stage of Acceptance	Water and wastewater utilities are increasingly more willing to turn off equipment once they understand that system requirements can still be achieved.

G9 – Electric Motors: Install High-Efficiency Motors

Best Practice	Survey existing motors for possible replacement with new, high-efficiency motors and specify the most energy-efficient motors on all new installed and inventoried equipment. Include an emergency motor replacement program that specifies energy-efficient motors.
See Also	G10 - Electric Motors: Automate To Monitor and Control G12 - Electric Motors: Variable Frequency Drive Applications G13 - Electric Motors: Correctly Size Motors
Primary Area/Process	Can be applied to all electric motors, especially on well and booster pumps for water systems and on wastewater facility motors with high annual operating hours and those that operate during on-peak hours, e.g. aeration blowers, disinfection systems, pumps and clarifiers.
Productivity Impact	Limited impact for a short shutdown for removal of the existing motor and installation of the new motor.
Economic Benefit	The simple payback is generally short, often less than two years, if the motor operates continuously. However, if the equipment's annual hours of operation are minimal, the simple payback period will become extended.
Energy Savings	Savings will vary, but should be between 5% and 10% of the energy consumed by the motor being replaced.
Applications & Limitations	The physical characteristics and location of the existing motor must be considered when replacing a motor. For example, the new motor may have to be explosion-proof, spark-resistant or have immersion capability (flooding conditions).
Practical Notes	Typically, when an existing motor is replaced or needs to undergo major repairs, a high-efficiency motor is used. Often times, such as under conditions of high annual operating hours, it may be worthwhile to replace a working motor. The size of the existing machine should be assessed to determine if has the operating range to be energy-efficient. Often a machine may be oversized to meet maximum design flow although the plant may never reach that flow. It is sometimes advantageous to add a smaller machine to process average flow while keeping the large machine in place to meet maximum design flow requirements. Determine if it is economically justifiable to replace older motors instead of repairing them. Since a premium-efficiency motor may require a longer delivery time than a standard or high-efficiency motor of the same size, allow adequate time in the project schedule.
Other Benefits	Reduced emissions from the power source of the motor (electric utility).
Stage of Acceptance	This is a well-known, proven and accepted technology.

G10 – Electric Motors: Automate to Monitor and Control

Best Practice	Use automatic controls where feasible to monitor, record and control system functions in order to optimize energy consumption, production demands and treated flows.
See Also	G9 – Electric Motors: Install High-Efficiency Motors G11 – Supervisory Control and Data Acquisition G12 – Electric Motors: Variable Frequency Drives Applications
Primary Area/Process	Automatic controls apply to many aspects of water and wastewater treatment processes.
Productivity Impact	Except during installation, minimum impact. The temporary disruption should yield high future returns in operational control. A control system should improve system performance.
Economic Benefit	Payback varies significantly, depending on the complexity of the controls required.
Energy Savings	Typically, energy savings result from the ability to match equipment performance to the real time demands of the treatment, distribution, or collection system. Variable frequency drives, integrated with Dissolved Oxygen (DO) probes, are a good example.
Applications & Limitations	Control technologies vary from simple applications, such as timing clocks used to prevent large equipment from operating during on-peak rate periods, to complex systems like filter backwash monitoring, to control equipment operation based on a number of variables, or to the automatic monitoring of dissolved oxygen, integrated with blower speed control.
Practical Notes	Care must be taken in the design and installation of any automatic control system to ensure it is fully integrated and can meet operational requirements, especially in emergency situations. Make sure that system components needed for emergency situations are available. Look for vendors with process and control experience to optimize the entire system.
Other Benefits	The use of automatic monitoring and control systems to operate a facility may lead to a more in-depth understanding of facility operations.
Stage of Acceptance	Acceptance of automatic monitoring and controls in the water and wastewater industry is increasing with simple applications being viewed as “safer” and more complex application slowly gaining acceptance.

G11 – Supervisory Control and Data Acquisition (SCADA)

Best Practice	SCADA systems refer to the hardware and software systems that allow operators of distribution, collection and treatment systems to remotely monitor field parameters and equipment operation and also make adjustments to process parameters. SCADA systems provide the human machine interface (HMI) that allows operators to interact more easily with the various electronic monitors and controls used in water and wastewater systems. SCADA can improve energy use tracking with routine energy "benchmarking", including: • Monitoring energy use over time, including comparisons with process variables orkey performance indicators, such as flow rate, chemical use, pounds of BOD and pounds of TSS. • Offsetting loads and control motor operating times to manage on-peak electric demand.
See Also	G10 - Electric Motors: Automate To Monitor and Control
Primary Area/Process	Instrumentation and Controls.
Productivity Impact	Minimum impact after installation. Control systems should improve system performance.
Economic Benefit	Payback varies significantly depending on the extent and complexity of the monitoring and control system installed.
Energy Savings	Typically, energy savings result from the ability to match equipment performance to the real-time demands of the system.
Applications & Limitations	The capital investment required to implement a SCADA system can be cost prohibitive for some smaller utilities. Utilities that already use SCADA will also incur some additional capital costs for adding energy monitoring capabilities and defining energy benchmarking reports.
Practical Notes	An understanding of energy consumption through monitoring and tracking can make energy management less complicated.
Other Benefits	Use of a SCADA system for equipment and process control can also benefit the entire water and/or wastewater system by highlighting problem areas.
Stage of Acceptance	SCADA systems are widely accepted in the water and wastewater industry. Cost is often the greatest barrier to adoption.

G12 – Electric Motors: Variable Frequency Drive Applications

Best Practice	Variable frequency drives (VFDs) match motor output speeds to the load requirement and avoid running at constant full power, thereby reducing energy consumption. Equipment must be designed so they can operate at peak flows. Peak load designs often do not allow for energy-efficient operation at average or low flow conditions. Assess variations in facility flows (also variations in varying organic loads) and apply VFDs, particularly where peak process demands are significantly higher than the average or low demand and where the motor can run at partial loads to save energy.
See Also	G10 – Electric Motors: Automate to Monitor and Control.
Primary Area/Process	VFDs apply to most processes in water and wastewater systems where flows fluctuate. They can replace throttling valves on discharge piping, control the pumping rate of a process pump, control conveyance pressure in forcemains, control air flow rates from blowers and control the speed of oxidation ditch drives.
Productivity Impact	Impact should only be short term with interruption of service during installation, start up and fine tuning.
Economic Benefit	VFDs are now more available and affordable, with paybacks ranging from six months to five years. The payback period will vary with application depending on the size of the drive, hours of operation and variation in load. Large drives, long hours and high load variability yield the highest savings.
Energy Savings	Savings vary with application and technology. Many VFD retrofits have saved 15% to 35%. In some installations, particularly where throttling is used to control flow, savings of 10% to 40% are possible. Applied to a wastewater secondary treatment process, a VFD can save more than 50% of that process's energy use.
Applications & Limitations	Applications for VFDs include controlling pressure, daily demand (gpm), fire flow and well recovery and replenishment. Other applications include controlling aeration blowers, the pumping rate of raw sewage and sludge processing.
Practical Notes	Calculations that account for load variation and demonstrate the energy savings benefit can help justify the cost. The system must be reviewed by an expert before selecting and installing the VFD to ensure system compatibility and cost-effectiveness. VFDs allow operators to fine tune their collection, conveyance and treatment processes. Matching drives to loads also puts less stress on equipment and may reduce maintenance.
Other Benefits	Associated benefits include better control of system flow rate and pressure, more consistent supply and increased flexibility to meet demand requirements with minimum energy use. Better control of process flows can lead to reduced chemical usage. Reduced emissions from the power source directly related to the reduced consumption of electrical power is another benefit.
Stage of Acceptance	Widely accepted and proven in the water and wastewater industry. New and upgraded water and wastewater systems are commonly equipped with VFDs for most system applications.

G13 – Electric Motors: Correctly Size Motors

Best Practice	Properly size motors for the specific application, especially where load factors are relatively constant. Motors should be sized to run primarily in the 65% to 100% load range. In applications that require oversizing for peak process loads, alternative strategies, such as the use of a correctly sized motor backed up with a larger motor that only operates during process peak demand, should be considered.
See Also	G9 – Electric Motors: Install High-Efficiency Motors.
Primary Area/Process	All electric motors.
Productivity Impact	No productivity impact should result from this best practice, except for minimal impact during installation.
Economic Benefit	Savings will vary depending on motor size and application.
Energy Savings	Savings will vary depending on motor size and application.
Applications & Limitations	None.
Practical Notes	Many motors are oversized for their application, thereby wasting energy. Oversized motors can also result in a lower power factor. Motors that are oversized by more than 50% should be replaced with correctly sized, high-efficiency or premium-efficiency motors.
Other Benefits	None.
Stage of Acceptance	Not applicable.
Results	The Department of Energy has developed a popular motor selection and management tool: MotorMaster+ software. This free software includes a catalog of more than 25,000 AC motors and features motor inventory management tools, maintenance log tracking, predictive maintenance testing, energy efficiency analysis, savings evaluation capabilities and environmental reporting. The motor load and efficiency values are automatically determined when measured values are entered into the software. MotorMaster+ can quickly help water/wastewater systems identify inefficient or oversized motors and readily calculate the savings that can be achieved with more energy-efficient models. To download MotorMaster+, visit: https://www1.eere.energy.gov/manufacturing/tech_assistance/software_motormaster.html

G14 – Electric Motors: Properly Maintain Motors

Best Practice	A regular program of preventive maintenance can increase motor efficiency and prolong service life. A typical maintenance program should include: • Performance monitoring. Periodic measurements of power consumed in comparison to an initial baseline. • Measurement of resistance provided by winding • Insulation inspection (Megger testing). • Proper lubrication of motor bearings. • Verification of proper motor coupling alignment,or belt alignment and tension. • Cleaning of cooling vents. • Maintenance of protective circuitry, motor starters, • controls and other switchgear. • Recording the hours of operation
See Also	Not applicable.
Primary Area/Process	All electric motors.
Productivity Impact	No impact except for minimal impact during motor maintenance.
Economic Benefit	The resources allocated for preventive motor maintenance should be balanced with cost considerations and expected benefits. Preventive maintenance will ensure performance to specifications and longer equipment life.
Energy Savings	The energy savings will depend on the status and operating conditions of the equipment.
Applications & Limitations	None.
Practical Notes	None.
Other Benefits	Preventive maintenance benefits all processes in a water/wastewater system and reduces O&M costs.
Stage of Acceptance	Preventive maintenance of electric motors is a recognized best practice in the water and wastewater industry.

G15 – Electric Motors: Improve Power Factor

Best Practice	Improve the power factor of electric motors by minimizing the operation of idling or lightly-loaded motors, avoiding operation of equipment above its rated voltage, replacing inefficient motors with energy-efficient motors that operate near their rated capacity and installing power factor correction capacitors.
See Also	Not applicable.
Primary Area/Process	All electric motors.
Productivity Impact	No productivity impact should result from this best practice, except for minimal impact during installation if motors are replaced.
Economic Benefit	Electric utility savings will accrue, due to a lower utility service charge, but not in actual reduced energy costs.
Energy Savings	See above.
Applications & Limitations	The installation of either single or multiple banks of power factor capacitors is especially beneficial in facilities with larger motors. Many electric utility companies charge the facility if the power factor is less than 0.95.
Practical Notes	Periodic monitoring of power efficiency and load factors can provide valuable information, including inefficient motor operation or potential motor failure. A motor's efficiency tends to decrease significantly when operated below 50% of its rated load and the power factor also tends to drop off at partial load. Replace motors that are significantly oversized with more efficient, properly-sized motors.
Other Benefits	Motors and drives require proper and periodical maintenance to ensure they are operating at optimum performance. Periodic monitoring of power efficiency and load factors can provide valuable information, including inefficient motor operation or potential motor failure.
Stage of Acceptance	This is standard practice and utilities seek to have their customers improve power factor on their systems.

G16 – Pumps: Optimize Pump System Efficiency

Best Practice	Identify the optimum operational conditions for each pump and perform a system analysis. This analysis should include the start-up flows (present low flows) and progress to the design flow capacity, usually a twenty-year forecast of flow with a peaking factor to identify the range of flow(s) and head conditions required to meet the conditions and specifications of the system design in an energy-efficient manner. Select the pump or combination of pumps that provide the peak efficiency point relative to the common operation condition of the pump. Consider operating a single pump, multiple pumps, multiple pumps of different capacities and the use of VFDs.
See Also	G12 – Electric Motors: Variable Frequency Drives Applications G17 – Pumps: Reduce Pumping Flow G18 – Pumps: Reduce Pumping Head
Primary Area/Process	This Best Practice should be applied to all pumping applications.
Productivity Impact	Optimizing pumping systems can reduce unscheduled downtime, reduce seal replacement costs and improve process treatment efficiency and effectiveness.
Economic Benefit	The payback period depends on site specifics and whether it is applied to a new design or retrofit. With a new facility, the payback period should be less than two years; in retrofit conditions, three months up to three years is a typical range.
Energy Savings	The energy saved will vary with the installation; 15% to 30% is typical, with up to 70% available in retrofit situations where a service area has not grown as forecasted.
Applications & Limitations	None.
Practical Notes	Many computer models can help with the analysis. The model should address both static and dynamic conditions and present and future pumping conditions.
Other Benefits	Generally, improved pumping systems provide better treatment system control.
Stage of Acceptance	The technologies used to analyze pumping systems are readily available and their use is widely accepted.
Results	The Department of Energy (DOE) has developed a tool — the Pump System Assessment Tool (PSAT)—that can be used together with the Hydraulic Institute's Achievable Efficiency Estimate Curves to determine the achievable and optimum efficiencies for the selected pump type, as well as correction factors for specific operating conditions. This method can be used to calculate the energy savings based on the difference between the anticipated energy use of a high-efficiency pump and the baseline energy use associated with inefficient or oversized proposed or existing pumps.

G17 – Pumps: Reduce Pumping Flow

Best Practice	Manage pumping flow rate. Energy use in a pump is directly proportional to the flow rate being pumped. Compare design flow rate with current flow rate and evaluate whether or not system conditions have changed. In some applications (e.g., pumping to a storage tank), it is possible to pump at a lower flow rate over a longer period of time, allowing for operation of the pump(s) at optimal location on the pump curve for energy efficiency. Conservation measures such as the reduction of infiltration and inflow or leak detection and repairs to the water distribution system can also reduce the flow rate required.
See Also	G16 – Pumps: Optimize Pump System Efficiency W3 – System Leak Detection and Repair W6 – Optimize Storage Capacity W7 – Promote Water Conservation
Primary Area/Process	This energy saving practice can be applied to all pumping systems.
Productivity Impact	No impact.
Economic Benefit	The estimated payback will vary with improvements and comparison with a base alternative. While load shifting and demand flattening (pumping at a lower rate over a longer period of time) do not necessarily result in reduced energy use, they do result in reduced electricity bills (on-peak demand savings).
Energy Savings	The potential savings will vary with the type of modifications being considered.
Applications & Limitations	All pumping systems.
Practical Notes	A detailed evaluation should be completed to identify the potential energy savings for each installation.
Other Benefits	None.
Stage of Acceptance	Not applicable.

G18 – Pumps: Reduce Pumping Head

Best Practice	Reduce the total system head losses, which include static head and friction head losses (due to velocity, bends, fittings, valves, pipe length, diameter and roughness). Energy use in a pump system is directly proportional to the head. Plot the system curve at the time of installation and compare output on the certified curve for that pump model and size. Calculate the system efficiency and save for future reference. Plot the system curve on a yearly basis; examine and re-plot at shorter time periods if problems develop. Avoid throttling valves to control the flow rate. Run higher wet well level on the suction side (if practical). Increase pipeline size and/or decrease pipe roughness. Modify header configuration to minimize fittings.
See Also	G16 – Pumps: Optimize Pump System Efficiency G19 – Pumps: Avoid Pump Discharge Throttling
Primary Area/Process	This best practice can be applied to all pump systems.
Productivity Impact	No impact.
Economic Benefit	The estimated payback will vary with improvements and comparison with a base alternative.
Energy Savings	The potential savings will vary with the type of modifications being considered.
Applications & Limitations	Applicable to all pumping systems. Note that reducing the head too much may result in the pump running to the far right of the best efficiency point (BEP) on the pump curve, which could result in inefficient operation and/or cavitation.
Practical Notes	A detailed evaluation should be completed to identify the potential energy savings for each installation.
Other Benefits	Reduced pump wear, longer service life and less maintenance are additional benefits.
Stage of Acceptance	Reducing the head on pumping systems is readily accepted in the water and wastewater industry.

G19 – Pumps: Avoid Pump Discharge Throttling

Best Practice	Modify the operation of a pumping system to eliminate the use of valve throttling to control the flow rate from pumps. Consider energy-efficient variable speed drive technologies, such as variable frequency drives (VFDs). Also consider the utilization of a lower capacity pump.
See Also	G12 – Electric Motors: Variable Frequency Drives Applications.
Primary Area/Process	This technology is most often applied to well and booster pump discharges. However it also is used in wastewater pump stations.
Productivity Impact	No impact.
Economic Benefit	Payback varies by application and may be less than one year if pump run-time is high and valve closure is significant. Still, the savings can be as low as 15% of total energy consumption if the pump has low hours of operation and the throttling valve is minimally closed.
Energy Savings	Energy savings can exceed 50% of pumping energy in some cases. Actual energy savings depends on the amount of closure of the throttling valve.
Applications & Limitations	All locations currently using valves to control flows.
Practical Notes	A detailed evaluation should be completed to identify the potential energy savings for each installation, giving some consideration to the use of a variable frequency drive and/or smaller-sized pumps.
Other Benefits	Ability to quickly and easily adjust flow as changes occur in the distribution system or in the ability of a well to recharge. Reduced pump wear, longer service life and less maintenance are additional benefits.
Stage of Acceptance	The water/wastewater industry accepts the use of VFDs to replace throttling valves in order to reduce energy consumption and provide improved control of the pump.

G20 – Filtration: Sequence Backwash Cycles

Best Practice	A filtration system can have high energy consumption and power demand. The highest energy users in filtration systems are typically the backwash pumps and aeration blower if it is an air-assisted backwash system. Consider sequencing and shifting the backwash cycles to off-peak backwash periods to reduce the electric on-peak demand. In some applications, it is possible to pump at a lower rate over a longer time to a water storage tank located at a higher elevation and backwash using gravity flow. Also, if the backwash system includes air-assist assess the operation to determine if the blower can be reduced in size.
See Also	Not applicable.
Primary Area/Process	Single media or multi-media granular or membrane filtration systems are applied to water systems and in tertiary treatment of wastewater systems.
Productivity Impact	Productivity should not be impacted by sequencing of backwash cycles. Ensuring availability of sufficient filtration capacity is the primary concern.
Economic Benefit	Savings will result from a lower on-peak electric demand due to the shifted and staggered operation of backwash pumps and/or aeration blower.
Energy Savings	Energy savings (kWh) are generally minor. Utility bill savings result from reduced on- peak demand (kW).
Applications & Limitations	When operators must be present, backwashing during off-peak time can affect staffing needs and labor costs.
Practical Notes	None.
Other Benefits	Sequencing of backwash cycles provides for a more stable and constant operation of filter units. Backwashing during off-peak times also provides an opportunity to treat the backwash wastewater during off-peak electric rates.
Stage of Acceptance	Sequencing of backwash cycles is an accepted practice.

G21 – Ultraviolet (UV) Disinfection Options

Best Practice	Consider various ultraviolet (UV) disinfection system design or redesign options that can be configured by reducing the number of lights (bulbs), bulb orientation, bulb type (pressure and intensity), turn-down ratio (bank size and bulb output variability) and dose-pacing control (system output automatically controls to disinfection requirement).
See Also	Not applicable.
Primary Area/Process	UV disinfection options can apply to both water and wastewater systems.
Productivity Impact	Minor impact on productivity during the installation of any improvements.
Economic Benefit	Paybacks will vary depending on the following: current type of UV system in use, range of energy-efficiency renovations available, peak design and average flow to be treated, disinfection limit and upstream treatment processes and current and future energy costs.
Energy Savings	Energy savings from UV result when the number of lamps "on" and lamp output are paced, based on flow rate and transmittance. Low-pressure, high-output UV lamps use about 50% less energy than medium-pressure lamps. Typical energy requirements for low-pressure, high-output systems range from 3.2 to 4.8 kWh/mgd, while medium-pressure systems use about 6.8 kWh/mgd. Sleeve cleaning alone can save 10% of UV system energy consumption.
Applications & Limitations	Yearly energy savings may be lower for systems that operate seasonally, due to limited annual hours of operation.
Practical Notes	Medium pressure lamps convert a lower percentage of the power they consume into useful UV light, compared with low pressure/high-output lamps. Additionally, medium pressure lamps provide much lower turn-down capability. Consequently, a medium pressure system may use significantly more energy, despite having fewer lamps. Low-pressure UV lamps are typically used for flows not exceeding 38 mgd. For higher wastewater flows, or when space is limited, medium-pressure UV lamps are required. Including an automatic cleaning (wiping) system ensures that the quartz sleeves stay clean and that the maximum amount of UV can be transferred.
Other Benefits	Installation of an ultraviolet (UV) system usually replaces a chlorination system, thereby eliminating on-site storage of chlorine, which can be either a hazardous gas or corrosive liquid. Additionally, using UV disinfection reduces the potential for trihalomethane (THM) formation in the distribution system resulting from disinfection byproduct (DBP) precursors in the water.
Stage of Acceptance	Many varieties and configurations of UV disinfection systems are accepted and in use throughout the water and wastewater industry.

G22 – Energy Manager

Best Practice	Water and/or wastewater utilities should appoint an energy manager. The duties and responsibilities of the position need to be defined according to the needs of the utility. This position, where practical, should be full time. If possible, the position also should have the authority and budget for improving the energy efficiency of the existing system. The energy manager should be responsible for making sure that all new construction and equipment upgrades are energy-efficient from start and throughout the life-time of the improvements.
See Also	None
Primary Area/Process	All components of water and wastewater systems.
Productivity Impact	There should be no impact on production.
Economic Benefit	Having a manager does not guarantee payback. However, an effective manager can produce significant returns on the investment. Payback on projects implemented as the result of having an energy Manager will vary by project and may range from a few months to years.
Energy Savings	Energy savings are derived from the incorporation of energy-efficient equipment and practices in the capital and operational modifications implemented.
Applications & Limitations	There are no limitations of this practice.
Practical Notes	The manager needs to have defined responsibilities and a budget in order to plan and implement new energy efficiency programs and projects.
Other Benefits	Other benefits include a well-managed energy budget and optimized energy utilization. The manager may also support energy-related budget proposals before the governing commission.
Stage of Acceptance	Increasingly utilities are seeing the value of having an in-house champion that can promote, integrate and shepherd energy efficiency projects to implementation.

G23 – Utilize and Manage Monitored and Recorded Data

Best Practice	Water and wastewater system operators are encouraged to monitor and record facility/station data, including influent flow, BOD, TSS, ammonia, dissolved oxygen, kilowatt consumption, kW demands and therms. This data should be organized and managed so it becomes a usable tool in managing the operations as well as the energy usage of their water/wastewater system. The recorded data, developed into trend graphs and pie charts, provide a pictorial tool that can give insight into the operations, maintenance and administration of the system. For example, a trend graph of energy consumption versus influent flow can show the consistency or inconsistency of energy consumption with respect to operation. A similar plot of energy consumption versus organic load can be valuable in monitoring the impact of organic loading on the system. Having energy consumption data recorded for each piece of equipment can show load shapes and possible decay trends that can be valuable for benchmarking operations and in assessing where energy efficiency opportunities are available.
See Also	G1 – Facility Energy Assessment G2 – Real Time Energy Monitoring G6 – Electric Peak Reduction
Primary Area/Process	This practice should be applied at all water and wastewater systems.
Productivity Impact	The only impact would be minor disturbance during the installation of equipment associated with the practice.
Economic Benefit	Payback period will vary with the complexity of the installed data and the tools developed from the recorded data. However, more value will be obtained by reducing and better managing energy consumption.
Energy Savings	Savings will vary but can be in the range of 10% to 20 % of the total energy consumed by the system.
Applications & Limitations	There are few, if any, applications where data cannot be monitored, recorded and managed.
Practical Notes	There is value in applying this practice to all water/wastewater systems.
Other Benefits	Improved operation potentially resulting in improved water quality and longer life for equipment.
Stage of Acceptance	Improved data management and its application to problem-solving is increasingly becoming an accepted practice in water and wastewater system management.

G24 – Ensure Plant Personnel Receive, Review and Understand Monthly Energy Bills

Best Practice	All water and wastewater system superintendents/operators should receive and review their system's monthly energy bills. Energy utility bills are generally sent directly to the business office of the utility where they are opened, reviewed and paid. The majority of superintendents and operators never see their systems' monthly energy bills and miss the opportunity to gain valuable insight into their operations and budgets. Billing information, critical to understanding the impact of energy costs on operating budgets, includes on- peak and off-peak consumption (kWh) and peak demand (kW), time of peak, the unit costs for on- and off-peak use and the monthly demand charge component. The energy provider also shows 15 or 30 minute demand values. This information can show how the system is operating and indicate potential anomalies, such as excessive, unexplainable consumption. Interfacing energy and demand usage from energy utility bills with data on influent flow and organic strength can broaden the operator's understanding of the operation. Where practical, plant efficiency should be part of manager's overall performance evaluation.
See Also	*Appendix A*: *Understanding the Electric Bill*
Primary Area/Process	This practice should be applied to all water and wastewater systems. Monthly reviews and assessments should be completed and trend graphs continually updated.
Productivity Impact	There is no disruption to the operation of the system when assessing energy bills.
Economic Benefit	Economic benefit will vary depending on the aggressiveness of the program and the extent of potential operational changes and availability of capital investment funding when needed.
Energy Savings	Energy savings will vary depending on modifications. A modification could be as simple as changing the timing that a unit process operates (on-peak demand). Additionally, it could be the replacement of constant speed motors with variable frequency drives.
Applications & Limitations	None
Practical Notes	No limitations. Managers of all sizes of water and wastewater systems should understand when and how their systems consume energy.
Other Benefits	A better understanding of energy bills often results in more attention to the sequence of unit treatment operations. Wastewater treatment schedules can be optimized according to the time of operation.
Stage of Acceptance	Increasingly, utilities understand the value of the information they receive from their energy provider.

G25 – Utilize Life-Cycle Cost Analysis for Purchase Selection

Best Practice	Utilize life-cycle cost analysis when assessing and purchasing equipment, as opposed to selecting only the lowest first cost. Life-cycle cost analysis incorporates the energy efficiency of the unit over the lifetime of the equipment. Water and wastewater utilities, as regulated monopolies, often do not experience the same longevity risks of private companies. Since municipal water/wastewater treatment facilities (W/WWTF) are less exposed to economic conditions, they can usually consider longer lifetime projects whose costs can be absorbed in rates over the equipment life. This difference actually affords W/WWTFs the opportunity to look at the long-term picture in terms of costs, where life-cycle costs can be applied to investment decisions. This is especially important for energy efficiency project investment since the present value of energy savings over the life-time can be used to offset the initial capital cost of the energy efficiency improvement.
See Also	None
Primary Area/Process	Applicable to all equipment purchases and new construction investments by water or wastewater facilities. Particularly valuable when assessing large energy consumers and components that operate continuously.
Productivity Impact	No impact on productivity. Investment costs are generally built into water/wastewater utility rates which ultimately affect customer costs.
Economic Benefit	Evaluating capital projects using life cycle cost ensures that energy savings and total economic benefit are considered.
Energy Savings	Savings will vary depending on the extent of the improvement.
Applications & Limitations	None
Practical Notes	This best practice should be implemented for all purchases. An estimate of the equipment life-time and an understanding of present value concepts, well-understood by accounting professionals, can easily provide an estimate of life-cycle cost.
Other Benefits	Other benefits include lower operating costs, more stable rates and lower long-term costs for ratepayers.
Stage of Acceptance	Life-cycle cost analysis is becoming more utilized, particularly where energy costs are high and constitute a major portion of a utility's budget.

G26 – Energy Efficiency Projects Can Pay for Themselves

Best Practice	When analyzing the financial impact of an energy efficiency project, be sure to include the projected payback period, calculated on the basis of the energy savings. The inherent value of a good energy efficiency project is that it will eventually pay for its initial cost before it needs to be replaced. The water/wastewater facility management will determine whether the payback period is within the reasonable range of acceptability. The energy savings of an energy efficiency investment can be accounted for and used directly to offset the cost of amortizing the loan used to fund the project. When the loan is paid in full, the full value of the energy savings accrues to the water/wastewater system. Since many projects pay for themselves in less than 5 years, a considerable amount of future net benefit is usually available to the wastewater treatment facility (WWTF) for this investment.
See Also	None
Primary Area/Process	All projects that incorporate energy savings and/or on-peak demand reduction for a water or wastewater system.
Productivity Impact	There is no impact on productivity.
Economic Benefit	Where the energy savings are applied to the amortization of a loan for the equipment, payback does not have to be considered, as long as the amortization period is less than the lifetime of the equipment. Care should be taken to ensure that a reliable estimate of monthly savings is made and that the savings exceeds the loan payment. The ultimate benefit is the present value of the stream of energy savings that accrue once the equipment loan has been paid.
Energy Savings	Energy savings will vary depending upon the equipment being amortized.
Applications & Limitations	There are no limitations.
Practical Notes	While a WWTF's accounting department can typically manage the loan structure for an energy efficiency investment, due diligence would require an estimate of energy savings from a reliable energy efficiency engineer. External resources, such as energy service companies, are also available to facilitate this type of loan agreement. A detailed assessment of the present operating conditions and proposed design conditions is necessary. The assessment needs to identify present day (existing) conditions, low-flow conditions and proposed 20-year design conditions. The full range of operation should be considered when selecting equipment.
Other Benefits	Under a properly structured loan, the WWTF experiences only positive cash-flow, i.e. the energy savings exceed the amortization cost.
Stage of Acceptance	This best practice is gaining acceptance as water/wastewater systems come to understand how energy savings can pay for even major investments.

G27 – How Do I Implement Energy Efficiency and/or Renewable Energy Projects

Best Practice	Every water/wastewater system should develop a strategy to implement energy-efficient (EE) and/or renewable energy (RE) projects. EE and RE project implementations are critical components of sustainability ("Green") goals. A first step in this strategy is to develop a cost analysis approach that incorporates the cost of energy consumption for the projected life of the equipment being purchased (life-cycle costing). This can show how the project will pay for itself and meet an acceptable payback. The analysis may also describe features that can provide additional savings: reduced maintenance, shorter downtime, greater reliability of operation, no chemical conditioning costs, etc. This analysis should compare the benefits and costs of the proposed improvements versus the costs of the current operation. In addition to energy savings, the payback assessment should include all ancillary attributes. If the payback is acceptable, the water/wastewater treatment facility (WWTF) should move the capitalization process forward.
See Also	G25 – Utilize Life-Cycle Cost Analysis for Purchase Selection
Primary Area/Process	This practice applies to all energy efficiency and renewable energy projects
Productivity Impact	Minimal impact during implementation.
Economic Benefit	The estimation of the payback period provides the argument for management. If the payback is within an acceptable range, management should invest in the project.
Energy Savings	Energy savings will vary with each project.
Applications & Limitations	None, all projects need to be analyzed.
Practical Notes	All projects should be analyzed to identify what savings they achieve for the water/wastewater system when implemented. A truly effective strategic plan will include a list of proposed improvements along with their priority, a schedule for completion and their estimated costs and savings.
Other Benefits	Utilizes more-informed, analytical business practices in decision making that ultimately benefits ratepayers.
Stage of Acceptance	Identifying and implementing energy-efficient and renewable energy projects is gaining industry acceptance.

G28 – Pump Station Assessment

Best Practice	Water and wastewater systems should develop an energy efficiency assessment of each of their pump stations. Design codes require a variety of flow rate conditions to be achieved. As the result, water/wastewater utilities select most pumps with the intent to meet peak-flow conditions. They will also typically provide a redundant back-up unit for emergencies or unforeseen peaks. This results in many pumps that are too large to be energy-efficient for most of their daily operating loads. While often not considered in pump selection, the water/wastewater utility should consider current operating conditions or start-up low-flows. The water/wastewater system should determine the power consumption of the pumping system (motor, drive and pump) across the range of pumping rates, from current flow up to design flow. Measured data can be used to construct a pump performance curve for the installed system. The actual performance curve should be compared to the manufacturer's pump curve to find the system's actual performance. This comparison will provide insight to the energy efficiency of the installed system and support an analysis of savings that may be achieved if a motor, pump, or drive is added or changed. Most water/wastewater pump stations can benefit from a variable speed drive or new or additional pump, selected on the basis of average and/or low flow conditions.
See Also	G16 – Pumps: Optimize Pump System Efficiency G17 – Pumps: Reduce Pumping Flow G18 – Pumps: Reduce Pumping Head G19 – Pumps: Avoid Pump Discharge Throttling
Primary Area/Process	All systems with active pump stations.
Productivity Impact	Minimal impact other than during collecting and recording operating data.
Economic Benefit	Payback will vary with each pump station assessed, with respect to size (hp), operating time and schedule.
Energy Savings	Energy savings will vary by project but can range from 20 to 50% of pumping energy. Actual savings will depend on the type of modification being considered.
Applications & Limitations	All pumping systems
Practical Notes	A complete analysis is required before deciding which modification to implement.
Other Benefits	Improved understanding of the condition of all of the components of the pump station. Also, potential reduction in wear and tear on the pumping equipment in the pump station.
Stage of Acceptance	Assessing pump stations in water and wastewater systems is a readily accepted practice and one that is continually gaining more interest and implementation.

WATER BEST PRACTICES

Checklist for Water Best Practices

Best Practice Analyzed? (Date)	Further Review Needed? (Yes/No)	Best Practice Possible? (Yes/No)	#	Best Practice	Typical Energy Savings of Unit Process (%)	Typical Payback (years)
			1	Integrate System Demand and Power Demand	Variable	Variable
			2	Computer Assisted Design and Operation	Variable	Variable
			3	System Leak Detection and Repair	Variable	Variable
			4	Manage Well Production and Draw Down	Variable	Variable
			5	Sequence Well Operation	Variable	Variable
			6	Optimize Storage Capacity	Variable	Variable
			7	Promote Water Conservation	Variable	Variable
			8	Sprinkling Reduction Program	Variable	Variable
			9	Manage High Volume Users	Variable	Variable
			10	Energy-Efficient Membrane Treatment	Variable	Variable

NOTES:

W1 – Integrate System Demand and Power Demand

Best Practice	Evaluate current system demand (water consumption) and electric power demand (on and off-peak). The analysis should address residential, commercial, institutional and industrial usage plus required fire flow. Utility staff should direct system designers to incorporate energy efficiency best practices in all designs, new and retrofit, to reduce electric on-peak demand and energy consumption. For well pumps and booster pump stations, consider the feasibility of applying variable speed drives and electric power monitoring, as well as demand controls, to minimize on-peak demand charges.
See Also	Not applicable.
Primary Area/Process	Includes all electrical components of water supply, treatment and distribution systems.
Productivity Impact	The evaluation will have no impact on production. Water production and distribution is assumed to improve for either a new system or retrofit.
Economic Benefit	The estimated payback period, not tied to the evaluation itself, will vary with the extent of proposed improvements and comparison with a base alternative.
Energy Savings	The purpose of the evaluation is to identify potential savings. The potential savings will vary with the type of modifications being considered.
Applications & Limitations	The evaluation should advise the comprehensive planning process prior to the development of any improvement project.
Practical Notes	Careful evaluation and planning can lower capital costs by ensuring that system improvements are appropriate and new/retrofit equipment is compatible with existing system components.
Other Benefits	Other benefits include improved production scheduling and the potential for greater environmental compliance. Also, lower utility costs mean lower customer bills and more satisfied customers.
Stage of Acceptance	Careful planning of system improvements has long been a hallmark of the water industry. This practice builds on this concept by incorporating the goal of energy efficiency and on-peak demand management.

W2 – Computer-Assisted Design and Operation

Best Practice	Develop a computer model of the water distribution system to evaluate the impacts of proposed improvements. A system-specific computer model can evaluate the impacts on the distribution system from changes in pipe size, pumping rates, pump operating point, system pressure, location of booster pumps, location of storage and variable flow rates. Adjusting system pressures, pump rates, pump operating points and operational sequence can improve energy management.
See Also	Not applicable.
Primary Area/Process	All water distribution systems.
Productivity Impact	No impact on operation or production. Field sampling may be necessary to calibrate the model to reflect actual field conditions.
Economic Benefit	Payback will be a direct function of the identified opportunities for energy savings. Payback benefits begin when the model is used to select energy-efficient practices and equipment.
Energy Savings	The potential energy savings will vary with the types of modifications being considered.
Applications & Limitations	This measure can benefit systems of all sizes. System pressure must always be maintained at a sufficient level to meet customer demand, fire flow and code requirements.
Practical Notes	Many computer models are available. The model should address both static and dynamic conditions. Look for user friendliness and expandability to allow the model to change and grow with the system. Perform analyses prior to new construction, to minimize capital costs and ensure the best long-term decisions.
Other Benefits	Computer modeling can help document and justify infrastructure and operation decisions to management. It also provides data for annual reports and information needed for asset management.
Stage of Acceptance	Use of modeling technology for operations optimization is well received and widely accepted by the industry.

W3 – System Leak Detection and Repair

Best Practice	Review your facility's annual Public Utility Commission water reports to determine the amount of water that is unaccounted for. If the amount exceeds "typical" losses for similar facilities, use leak detection technology to identify the location of water loss and repair identified leaks. In addition to reducing water loss, repairing leaks can reduce pumping energy requirements. Operations and maintenance (O&M) practices, such as pipe inspection and maintenance programs and meter inspection and replacement programs, are critical. New technology, such as automatic meter reading (AMR) technology and Computerized Maintenance Management Software (CMMS), can also be useful tools to identify leaks.
See Also	G17 – Pumps: Reduce Pumping Flow
Primary Area/Process	Throughout all water distribution systems.
Productivity Impact	There may be minor disruptions during repair and disinfection of the section repaired before placing it back into service.
Economic Benefit	Payback varies considerably depending on the size and complexity of the distribution system and the extent of any required repairs. Payback periods tend to be longer than those for other energy efficiency projects since the energy savings may be small compared with the cost to repair the leak. The economic evaluation should also include the value of unaccounted water.
Energy Savings	Potential energy savings will vary with the number and severity of leaks, as well as system pressure.
Applications & Limitations	Applicable to all distribution systems.
Practical Notes	The amount of energy saved is small relative to the cost of repairing leaks in water mains because excavation in paved areas is expensive.
Other Benefits	The State Water Commission may require water loss testing in the future. Tying leak test to energy efficiency is a way to leverage resources.
Stage of Acceptance	Leak detection and repair is standard practice in the industry, but has traditionally been viewed as routine maintenance rather than as an energy efficiency practice.

W4 – Manage Well Production and Draw Down

Best Practice	Monitor, review and track the physical characteristics and operations of each well, including pumping rates, recharge capabilities, draw-down and recharge areas. Develop a performance chart or trend graphs that display historic and current conditions. Use this information to optimize the operation and planning of pumps, motors and the control system. Particularly, monitor well draw-down during pump operation to detect any production changes over time. Diminishing recharge may expose the potential for pump failure or other mechanical problems and may increase energy consumption. The water level may also drop to a point where pumping is inefficient.
See Also	W5 – Sequence Well Operation.
Primary Area/Process	All water systems with wells.
Productivity Impact	Impact felt only during installation, if new equipment is necessary. Failure of pumps or excessive draw-down would eventually lead to impact on water production.
Economic Benefit	A short payback is possible if equipment is in place and only requires adjustment. If new equipment, such as VFDs are required, the payback period will increase.
Energy Savings	Vary widely with the characteristics of each specific site.
Applications & Limitations	Metered operational data helps identify the “best point” for operation, which may make the system more energy-efficient. Some utilities may require the assistance of an external consultant.
Practical Notes	A strong maintenance program, coupled with monitoring and review, will always provide improved energy management. Maintaining a log of changes and trending results will also support system planning.
Other Benefits	Many additional benefits may accrue: lower stress on system, reduced pumping rate and reduced electric on-peak demand charge. An effective well management program allows for scheduled maintenance rather than emergency maintenance, makes fluctuations in the aquifer more predictable and reduces surprises and emergencies.
Stage of Acceptance	Widely accepted in the water industry. However, many utilities do not fully realize the value of monitoring the condition of wells and equipment and how it supports planned, preventative maintenance and avoids emergency maintenance.

W5 – Sequence Well Operation

Best Practice	First, compile and review all production information available on each well, including energy consumption. Become familiar with the functional characteristics and production capability of each well, noting that many wells are brought on line with equipment sized to achieve full capacity production, which may not be necessary. From these data, identify the proper sequence of well operations, beginning with the most energy-efficient well and ending with the least energy-efficient well.
See Also	W4 – Manage Well Production and Drawdown
Primary Area/Process	Water supply and distribution systems that are served by wells.
Productivity Impact	This practice should have little or no impact on productivity.
Economic Benefit	Paybacks are typically short because the practice of sequencing usually requires only a low-cost adjustment in procedures, rather than a capital investment, unless an automatic control system is required.
Energy Savings	Savings vary from system to system depending on the condition of existing equipment and current operations.
Applications & Limitations	One limitation is the potential that water quality and/or distribution issues may require the use of a less energy-efficient well over a more efficient one.
Practical Notes	This practice is easy to address since the data required to perform the analysis is already required for the annual Public Utility Commission report.
Other Benefits	Utility personnel can more accurately manage energy-efficient well production.
Stage of Acceptance	Widely accepted by the industry, but not many utilities have adopted this practice. Generally, its value is not fully understood.

W6 – Optimize Storage Capacity

Best Practice	Develop a storage capacity utilization strategy to minimize pumping during on-peak demand periods for electric power. Also develop a pump operation and water distribution strategy to flatten electric demand during the peak periods and shift as much pumping as possible to off-peak periods. • Track detailed water demand information by adding metering capabilities to water distribution and transmission lines. • Add or use existing storage capacity to minimize pumping costs during on-peak periods of electric power demand. • Use pressure-sustaining or pressure-reducing valves to assist in maintaining minimum pressure requirements in different regions of the water distribution system.
See Also	G17 – Pumps: Reduce Pumping Flow.
Primary Area/Process	Water distribution systems.
Productivity Impact	This practice should not impact productivity.
Economic Benefit	Payback will depend on the extent of capital improvements, such as addition of storage capacity. If only operational modifications are implemented, then there may be no capital cost.
Energy Savings	Utility bill savings result from reduced electric demand charges and will not likely come from a reduction in energy usage.
Applications & Limitations	The capital cost of additional storage, new valves and additional metering have to be balanced with expected savings from reduced electric demand charges. Minimum system pressure during on-peak flow periods and for fire flow protection must be maintained. Regulatory compliance cannot be undermined and should always be the primary goal.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Widely accepted by the industry.

W7 – Promote Water Conservation

Best Practice	Reducing water consumption on the customer side reduces the energy needed to treat and distribute water. Conservation can also assist with managing diurnal and seasonal peak demand periods. • Assess water conserving plumbing fixtures and appliances and promote them within the community. • Consider using a multi-tiered residential rate structure that charges a higher rate for high consumption (also known as an "inclined block" or "inverted" rate structure). • Target all customer classes – residential, commercial, institutional and industrial. • Offer water consumption audits for commercial and industrial customers. • Offer financial incentives for commercial and industrial customers to use more water-efficient systems for high water-use applications such as
See Also	G17 – Pumps: Reduce Pumping Flow W8 – Sprinkling Reduction Program
Primary Area/Process	All water utility customers, especially new construction and renovations requiring permits.
Productivity Impact	No impact.
Economic Benefit	Payback depends on campaign effectiveness, modifications in water utilization and the number of customer fixtures replaced.
Energy Savings	Savings will depend on the number and type of fixtures and appliances that are replaced. Savings will also be dependent on changes in consumer behaviors.
Applications & Limitations	All new construction and any renovations require permitting. The transition from flat rates to metered and/or conservation rate structures can be politically sensitive and requires significant public education and information. Successful water conservation programs can actually reduce revenues for a utility and the expected rate impact should be factored into fiscal and regulatory planning.
Practical Notes	Develop a list of manufacturers that make water conserving fixtures and appliances and make it available to all residential, commercial, institutional and industrial customers that inquire. The utility could also consider providing incentives to encourage water conservation, limiting landscape irrigation to overnight hours and providing educational classes on water conservation.
Other Benefits	Saving water, which is a limited, critical resource. Also, an effective program helps consumers adjust to long-term water conservation without major impact on their lifestyles.
Stage of Acceptance	Water conserving fixtures, appliances and practices are widely accepted in the industry and by consumers.

W8 – Landscape Irrigation Reduction Program

Best Practice	Establish a customer program that manages landscape irrigation to avoid on-peak water consumption and minimizes the duration of sprinkling. Automatically monitored and controlled irrigation systems have been shown to have a major impact on managing water consumption. Promoting and implementing this technology will reduce water consumption.
See Also	W7 - Promote Water Conservation.
Primary Area/Process	Water consumption/water distribution systems.
Productivity Impact	No impact on operations. May have beneficial impact by reducing well drawdown during poor well recharge times.
Economic Benefit	Payback period will be very short, if not immediate and begins when customers reduce their consumption.
Energy Savings	Potential energy savings, derived from reduced pumping costs, will vary with changes in customers' sprinkling habits.
Applications & Limitations	While there are no physical limits regarding landscape irrigation regulations, gaining customer cooperation and enforcing the regulations are real challenges.
Practical Notes	The utility must assess year around use and the potential to affect peak water consumption through rules that regulate time and duration of lawn sprinkling. The effort requires an information campaign backed up with enforcement. The water utility can also consider providing guidance for landscaping practice to reduce irrigation requirements (xeriscaping).
Other Benefits	Saving water, a limited, critical resource. Reduce well draw-down.
Stage of Acceptance	The effectiveness of this practice is widely understood and accepted. Still, gaining public acceptance can be a challenge since restricting lawn sprinkling may be viewed as an infringement of personal rights.

W9 – Manage High Volume Users

Best Practice	Meet with the top ten water users in your system to identify potential modifications to their operations that may reduce their water consumption and, consequently, energy consumption. Encourage them to adopt and even monitor the identified measures.
See Also	Not applicable.
Primary Area/Process	Water supply and distribution systems.
Productivity Impact	There is impact on the water utility. Any disruption during implementation would take place at the customers' facilities.
Economic Benefit	The payback for the water utility is nominal, since the only cost is for promotion of the program. Customer payback varies with the amount of water conservation and the complexity of the measures needed to achieve the savings.
Energy Savings	Energy savings are proportional to the reduction in water consumption.
Applications & Limitations	Since any reduction in water consumption results in a corresponding reduction in revenue, then each water utility has a limit on how much water can be conserved before it becomes necessary to modify the water utility rates.
Practical Notes	Minimize water utility rate impacts via thorough fiscal planning and regulatory rate development. Also, determine if customers' peak usage of water can be shifted to off-peak times for both electric and water savings. On-peak shifting of both electric and water consumption to off-peak demand periods, such as evening and nighttime hours, may reduce costs for both customer and water utility.
Other Benefits	This practice may extend the life of water supply and distribution systems and may also postpone costly future expansions. In industrial applications it may reduce the cost of producing their product.
Stage of Acceptance	Not widely adopted by utilities, due to the threat of reduction in utility revenue. Typically, customers respond favorably to this concept as long as the suggested measures do not negatively impact production, product quality or operation.

W10 – Energy-Efficient Membrane Treatment

Best Practice	Membrane bioreactor technology (MBR) is becoming a more competitive water treatment alternative when best available technology (BAT) is required to meet stringent water quality requirements. A MBR is a physical treatment option consisting of a thin layer of material capable of separating substances when a driving force is applied across the surface (membrane). Current MBR technology consists of microfiltration (MF), ultra-filtration (UF), nano-filtration (NF) and reverse osmosis (RO). The chosen option should correspond to the current water quality and be suitable for achieving the required water quality standards. Application of MBR technology can also provide additional advantages: reduced building size requirements; custom membrane designed to meet treatment requirements and improved staging implementation. A challenge that confronts membrane selection and application has been the potential impact on energy use. Experts have proposed that, to make this technology more energy-efficient, it will be necessary to reduce its air scour during backwashing. While this may help, greater impact may be achieved by initially designing the BAT based on the best turndown capability (sized to meet current flows and design flows energy-efficiently); simplifying the system; and selecting the best flux rate membrane for the application. MBR technology is a viable and applicable BAT for stringent treatment requirements. However, operational flexibility and energy efficiency must be incorporated into the design.
See Also	G4 – Comprehensive Planning Before Design
Primary Area/Process	Water treatment, particularly stringent quality requirements.
Productivity Impact	Installation can be done without interrupting the operation of the water system.
Economic Benefit	Payback will vary depending upon application as a retrofit or a new system.
Energy Savings	Energy savings will depend on the efficiency of the treatment system being retrofitted or the alternative new baseline treatment system it is being compared with.
Applications & Limitations	This treatment option applies particularly well to WTFs with limiting site conditions, poor water quality and stringent treatment requirements.
Practical Notes	MBR technology is becoming an acceptable option to consider because its capital cost is becoming more competitive compared with options that can meet stringent water quality requirements.
Other Benefits	MBR technology applications also provide other benefits: they can be automatically operated, have smaller space requirements, are highly reliable, provide a variety of membrane options to meet specific site requirements and are more adaptable to phased implementation.
Stage of Acceptance	Membrane technology is an acceptable treatment option that is gaining acceptance as treatment requirements become more stringent.

WASTEWATER BEST PRACTICES

Checklist for Wastewater Best Practices

Best Practice Analyzed? (Date)	Further Review Needed? (Yes/No)	Best Practice Possible? (Yes/No)	#	Best Practice	Typical Energy Savings of Unit Process (%)	Typical Payback (years)
			1	Operational Flexibility	10 – 25	< 2
			2	Staging of Treatment Capacity	10 – 30	< 2
			3	Manage for Seasonal /Tourist Peaks	Variable	4 – 6
			4	Flexible Sequencing of Basin Use	15 – 40	2 – 5
			5	Optimize Aeration System	30 – 70	3 – 7
			6	Fine Bubble Aeration	20 – 75	1 – 5
			7	Variable Blower Air Flow Rate	15 – 50	< 3
			8	Dissolved Oxygen Control	20 – 50	2 – 3
			9	Post Aeration: Cascade Aeration	Variable	Variable
			10	Sludge: Improve Solids Capture in Dissolved Air Flotation (DAF) Systen	Variable	Variable
			11	Sludge: Replace Centrifuge with Screw Press	Variable	Variable
			12	Sludge: Replace Centrifuge with Gravity Belt Thickener	Variable	Variable
			13	Biosolids Digestion Options	Variable	Variable
			14	Aerobic Digestion Options	20 – 50	Variable
			15	Biosolids Mixing Options in Aerobic Digesters	10 – 50	1 – 3
			16	Biosolids Mixing Options in Anaerobic Digesters	Variable	Variable
			17	Optimize Anaerobic Digester Performance	Variable	Variable
			18	Use Biogas to Produce Heat and/or Power	Variable	Variable
			19	Cover Basins to Reduce Aerosol and Odor Missions	Variable	Variable
			20	Reduce Fresh Water Consumption/ Final Effluent Recycling	10 – 50	2 – 3
			21	Anoxic Zone Mixing Options	25 – 50	3 – 5
			22	Biogas: Beneficial Utilization	Variable	Variable
			23	Biotower Energy Efficiency	15 – 30	Variable
			24	Energy-Efficient Membrane Treatment Options	Variable	Variable
			25	Blower Technology Options	15 – 25	1 – 7

NOTES:

WW1 – Operational Flexibility

Best Practice	Evaluate facility loadings and become familiar with the treatment systems in order to identify, plan and design the most energy-efficient and effective ways to operate the system while maintaining operational requirements. Options to consider include: • Operating fewer aeration tanks • Installing variable frequency drives so equipment operation can match system loadings • Installing dissolved oxygen monitoring and control equipment • Reducing air flow to the aeration tanks during low-load periods (usually nights and weekends) • Waiting to recycle supernatant during lower-flow periods, avoiding periods of high organic loading • Operating (bumping) diffusers or recycling backwash water during off-peak power demand periods • Install an extra, smaller capacity pumps along-side existing pumps to be able to meet both existing flows, low flows and design flows.
See Also	G12 – Electric Motors: Variable Frequency Drives Applications WW2 – Staging of Treatment Capacity WW3 – Manage for Seasonal/Tourist Peaks WW4– Flexible Sequencing of Basin Use WW5 – Optimize Aeration System W8 – Dissolved Oxygen Control
Primary Area/Process	This practice applies to grit removal, secondary treatment processes, all pumping operations, disinfection systems and biosolids management systems.
Productivity Impact	Implementation usually involves modifications to operations so there should be little or no impact on productivity.
Economic Benefit	Payback is generally within two years since most of the measures are operational adjustments and will not incur significant capital costs.
Energy Savings	Energy savings will vary depending on the measure. A typical range is from 10% to 25%.
Applications & Limitations	All facilities should apply this practice to reduce operating costs.
Practical Notes	Having an energy management plan (described in the first section of this handbook) will facilitate this practice. Measures should only be considered when there is flexibility in the facility and when they will not negatively impact meeting load requirements..
Other Benefits	Operations personnel will gain a better understanding of the capabilities of the treatment system they control.
Stage of Acceptance	Many facility operators accept the need to adjust operations in response to loadings once they learn the value and magnitude of the energy savings available.

WW2 – Staging of Treatment Capacity

Best Practice	When planning and designing improvements, wastewater system personnel and designers should develop and deploy a team that can determine how modular additions can be staged to meet current and projected treatment and design conditions. Staging construction according to smaller-sized, modular equipment so that new units can be brought on line as needed can both optimize a system's response to treatment demand and better manage energy usage and costs. For example, you could construct two aeration tanks and divide them in half, allowing for startup to be half of one tank, ramping up to one whole tank, then to one and a half tanks and finally to two tanks. The same concept can be applied to aeration blowers. They can be sized to meet incremental conditions all the way up to 20-year design conditions. If selected in small enough sizes, they may be brought on or off line, as air demand changes, to meet all conditions, from startup to design.
See Also	WW 1 – Operational Flexibility
Primary Area/Process	Staging is most applicable to the major energy users in a system, typically the secondary treatment process, pumping, disinfection and biosolids management.
Productivity Impact	Except for the instance when capital improvements are required, there should be no disruption to productivity. Usually a system will operate most efficiently when loaded nearer to its design load; therefore, staged systems will generally function efficiently throughout the life of the project.
Economic Benefit	The payback period will usually be less than two years because minimal system adjustments are required to implement staging.
Energy Savings	Proper staging of treatment capacity can achieve a savings of 10% to 30% of the total energy consumed by a unit process.
Applications & Limitations	Staging is applicable to all systems.
Practical Notes	Usually staging has a minor impact on construction and scheduling in exchange for the energy savings realized.
Other Benefits	Improved control of the system.
Stage of Acceptance	Staging of treatment capacity is accepted in the wastewater industry. However, it has not been readily adopted due to the belief that the entire system must be constructed to 20 year design specifications, rather than constructed in stages in response to increasing demand.

WW3 – Manage For Seasonal /Tourist Peaks

Best Practice	Flexible system design allows a utility to adjust and operate more energy-efficiently during peak tourist loadings as well as during the "off-season." In many areas tourism-related loadings versus off-season may reach as high as 10:1. These variable conditions may require idling treatment units during the off-season.
See Also	WW1 – Operational Flexibility WW2 – Staging of Treatment Capacity
Primary Area/Process	Primary areas of focus are the raw wastewater pumps. Secondary treatment processes include disinfection and solids management.
Productivity Impact	There is no productivity impact other than brief interruptions while new equipment is installed or placed into operation, if needed.
Economic Benefit	Most retrofit aeration modifications have paybacks of four years to six years. If the concept is integrated into the design of new construction, the payback should be less.
Energy Savings	Savings will vary, but can reach 50% during the off-season.
Applications & Limitations	Environmental and/or climatic considerations must be accounted for to prevent damage to seasonally out-of-service equipment.
Practical Notes	This strategy needs to be carefully analyzed to ensure that adequate treatment can be provided during the tourist season. The aeration tanks must be sized so they can be idled during the off-season. It helps to have several years of facility loading data and utility bills to assess seasonal variation to define the on- and off-peak seasons and their respective peak loadings for proper sizing of equipment.
Other Benefits	If the secondary treatment process is improved, generally the functions of other processes improve also.
Stage of Acceptance	These concepts are well known, understood and widely accepted.

WW4 – Flexible Sequencing of Basin Use

Best Practice	The selection of basin sizes can have a large impact on the energy consumed at a facility during its lifetime. The design team should review the existing and projected organic loadings to select the correct tank sizes. Typically, the use of smaller sized basins is beneficial so that early lifetime loadings can be processed effectively by a smaller basin. The remaining basins can then be loaded sequentially, as loads increase, until design capacity is reached. This approach allows for energy-efficient operation from start-up to design flow conditions.
See Also	WW1 – Operational Flexibility WW2 – Staging of Treatment Capacity
Primary Area/Process	Secondary treatment processes, particularly activated sludge treatment facilities.
Productivity Impact	None.
Economic Benefit	Payback for constructing multiple tanks will depend on space availability at the site. Implementation can be as simple as adding an interior wall to subdivide an existing tank. This can provide a two- to three-year payback. Payback may take three- to five-years for major site modifications.
Energy Savings	Energy savings of 15% to 40% are common if multiple smaller tanks are available to step the system into operations, compared with having only two large tanks.
Applications & Limitations	All facilities should consider operational flexibility in order to manage the continually varying facility loads.
Practical Notes	Facility personnel should work closely with designers throughout the design process. Information on the sizes and operation of basins required for a treatment process is invaluable to the selection process. Operating highly loaded smaller tanks, versus operating larger, under-loaded tanks, is preferred. Using intermediate tank walls (division walls) may be a simple, acceptable solution.
Other Benefits	Improves overall operation of the facility and can also reduce other associated treatment costs (lower polymer requirements) because solids are not over-aerated.
Stage of Acceptance	Acceptance varies from site to site based on facility staff preferences and experiences with taking tanks in and out of service.

WW5 – Optimize Aeration System

Best Practice	Assess the aeration system to determine if it is operating as energy-efficiently as possible for the required level of treatment. Assess present loading conditions and system performance through a comparison of kWh per million gallons and other key performance indicators (KPIs) with those of similar facilities. Consider the potential benefits and costs of improvements such as fine-bubble aeration, dissolved oxygen control and variable air flow rate blowers.
See Also	WW1 – Operational Flexibility WW6 – Fine Bubble Aeration WW7 – Variable Blower Air Flow Rate WW8 – Dissolved Oxygen Control
Primary Area/Process	Secondary treatment process activated sludge, aerobic digestion and post-aeration systems are the principal treatment processes where this energy saving practice can be implemented.
Productivity Impact	Modified aeration systems have also resulted in savings for other treatment unit processes. Savings have materialized in biosolids processing, particularly in reducing the polymer dosage for biosolids thickening and dewatering. Treatment capabilities have been increased at most facilities. In some locations, final effluent quality has improved.
Economic Benefit	The payback period is generally three to seven years for retrofits and about one year for new construction.
Energy Savings	Savings of 30% to 70% of total aeration system energy consumption are typical.
Applications & Limitations	All aerated treatment systems.
Practical Notes	This best practice should be implemented at all facilities with aeration opportunities unless there is an overwhelming reason to avoid it.
Other Benefits	Improvement in other unit treatment processes on site and reduced maintenance at some installations.
Stage of Acceptance	Fine-bubble aeration methods are widely accepted, as are dissolved oxygen monitoring and control systems and various methods of controlling the flow rate of air to the treatment process.

WW6 – Fine Bubble Aeration

Best Practice	Assess the feasibility of implementing fine bubble aeration at activated sludge treatment facilities. This practice provides energy-efficient treatment of wastewater. It can be installed in new systems or retrofitted into existing systems. The technology usually improves operations and increases the organic treatment capability of a wastewater treatment facility. For optimum performance, combine this practice with dissolved oxygen monitoring and control, a variable capacity blower and monitor blower pressure. Plan for periodic diffuser cleaning (in-place gas cleaning system or scheduled drain and manual cleaning), as diffuser fouling influences system pressure, oxygen transfer efficiency and energy-efficiency.
See Also	WW5 – Optimize Aeration System WW7 – Variable Blower Air Flow Rate WW8 – Dissolved Oxygen Control
Primary Area/Process	Primary application for this best practice will be on aeration tanks, aerobic digesters and post-aeration.
Productivity Impact	A minor impact on production will probably occur during installation.
Economic Benefit	Economic benefits vary from new facilities to retrofit applications. A new system may pay back in as little as one year. Payback on a retrofit will vary depending on the inefficiency of the existing system and the amount of new equipment required.
Energy Savings	Energy savings range from 20% to 75% of the aeration or aerobic digestion unit's energy consumption.
Applications & Limitations	This practice applies to all aeration systems. A limit exists for aerobic digestion – if the system operates at a solids concentration of 2.5% or greater, further review should first be done.
Practical Notes	Fine bubble technologies have applications for all sizes of wastewater treatment facilities. The percentage range of energy savings will be similar regardless of facility size.
Other Benefits	Most sites that have implemented this practice report improved biosolids management, reduced polymer usage, better clarification and better overall effluent quality.
Stage of Acceptance	This technology has gained a high level of acceptance in the industry.

WW7 – Variable Blower Air Flow Rate

Best Practice	Require that aeration system and aerobic digester blowers have variable air supply rate capability, such as single stage centrifugal blowers with VFD, positive displacement blowers with VFD, inlet guide-controlled multi-stage centrifugal blowers and/or turbo blower with a VFD. The range of variability should respond to the specific requirements a site needs to precisely match system demands. The blower system should be able to supply the minimum air flow required to meet existing low load conditions or mixing and to meet the high loads of design conditions. Avoid air flow discharge throttling and unnecessary back pressure.
See Also	WW5 – Optimize Aeration System WW6 – Fine Bubble Aeration WW8 – Dissolved Oxygen Control G12 – Electric Motors: Variable Frequency Drives Applications
Primary Area/Process	This practice applies to all aeration systems, including activated sludge aeration tanks, aerobic digestion systems and post aeration systems.
Productivity Impact	Interruption in production should occur only during installation.
Economic Benefit	Payback is usually under three years.
Energy Savings	Energy savings depend on site conditions and which parameter, mixing or organic loading, dictates the lesser amount of air flow required by the system. Savings will range from 15% to 50% of the energy consumed by this process.
Applications & Limitations	This practice can be applied wherever blowers are installed.
Practical Notes	Variable air flow rate blowers should be integrated with fine-bubble aeration and dissolved oxygen monitoring and control for optimum energy efficiency. Also consider the potential advantages of replacing two blowers and staging loadings with three, four, or five smaller units that can meet both current and future demands.
Other Benefits	When teamed with fine-bubble diffusers and dissolved oxygen (DO) control technologies, effluent quality and biosolids processing are usually improved.
Stage of Acceptance	Technologies for varying air flow rates are well received. Variable speed positive displacement blower arrangements and variable capacity centrifugal blowers are becoming more available and numerous installations now exist..

WW8 – Dissolved Oxygen Control

Best Practice	Consider dissolved oxygen monitoring and control technology that will maintain the dissolved oxygen (DO) concentration level of the aeration tank(s) at a preset control point by varying the air flow rate delivered to the aeration system.
See Also	WW1 – Operational Flexibility WW5 – Optimize Aeration System WW6 – Fine Bubble Aeration WW7 – Variable Blower Air Flow Rate
Primary Area/Process	The primary applications are on aeration tanks at activated sludge facilities and aerobic digestion and post-aeration systems.
Productivity Impact	Installation of most systems can be accomplished without interfering with normal operation.
Economic Benefit	Paybacks from improved monitoring and controls using DO control are usually two to three years.
Energy Savings	Savings vary depending on the efficiency of the present system. Generally, energy savings for an aeration system range from 20% to 50%.
Applications & Limitations	Limitations will vary with the characteristics of the waste being treated. If the waste has characteristics that can easily foul a DO probe, the DO system will not be readily feasible. Maintenance of the DO probe to preserve its monitoring capability is key to achieving maximum energy efficiency.
Practical Notes	This control should be employed at post-aeration systems and wherever activated sludge is used as the secondary treatment process. Variable flow may be provided with variable frequency drives (VFDs).
Other Benefits	Waste biosolids from a DO-controlled system have reportedly better dewatering characteristics. Also, a DO-controlled system usually has fewer problems treating a fluctuating influent load.
Stage of Acceptance	DO control is a well-established control methodology. The primary factor affecting acceptance is the concern about the reliability and associated maintenance costs related to DO probes.

WW9 – Post Aeration: Cascade Aeration

Best Practice	Consider the installation of a cascade aeration system for post-aeration applications. If the topography is favorable, this technology provides re-aeration of the effluent by increasing the water turbulence as it flows over the steps, without need for electricity.
See Also	Not applicable.
Primary Area/Process	Post aeration of a wastewater treatment facility's effluent.
Productivity Impact	Installation can be accomplished without interfering with normal operation.
Economic Benefit	Payback varies depending on the existing post-aeration system used.
Energy Savings	If cascade aeration is used to replace an existing post-aeration system that had either a subsurface diffuser system and blowers or a surface aeration arrangement, 100% of the replaced system's electricity used can be saved.
Applications & Limitations	The application is site-specific. About 10 to 15 feet of head (elevation differential) is needed between the final effluent point of discharge and the elevation of the receiving body of water, due to the low oxygen transfer rate and the temperature dependency of oxygen transfer.
Practical Notes	Adequate topographical conditions must exist to make this unit process applicable.
Other Benefits	Not applicable.
Stage of Acceptance	Cascade aeration for effluent re-aeration is a well-established method.

WW10 – Sludge: Improve Solids Capture in Dissolved Air Flotation (DAF) System

Best Practice	Optimize the air-to-solids ratio in a dissolved air Flotation (DAF) system by adjusting the supply air and or by feeding the highest possible solids content. Furthermore, energy use can be reduced by operating the DAF thickener continuously and adding polymers to the biosolids.
See Also	Not applicable.
Primary Area/Process	DAF thickeners are used in sludge thickening and dewatering processes.
Productivity Impact	No impact.
Economic Benefit	DAF thickeners have high operating costs because they require a significant amount of energy for air pressurization. Payback will vary depending on the degree of optimization.
Energy Savings	Energy consumption can be reduced by improving solids capture. Savings will depend on the application.
Applications & Limitations	Continuous operation of the DAF thickener and addition of polymers can increase O&M or labor costs.
Practical Notes	A comparison between the cost of the additional polymer and the avoided energy cost should be made in order to determine if the polymer addition is worthwhile.
Other Benefits	Improved solids capture will benefit the other biosolids treatment processes of thickening and/or dewatering downstream.
Stage of Acceptance	This practice is widely accepted by the industry.

WW11 – Sludge: Replace Centrifuge with Screw Press

Best Practice	Replace the biosolids dewatering centrifuge with a screw press.
See Also	WW12 – Sludge: Replace Centrifuge with Gravity Belt Thickener
Primary Area/Process	Biosolids thickening and dewatering.
Productivity Impact	Minimal impact during installation of equipment.
Economic Benefit	Payback will depend on the size of the application.
Energy Savings	Potentially high energy savings can be achieved by this best practice.
Applications & Limitations	A centrifuge is a relatively large energy consumer. Replacing a centrifuge with a screw press reduces energy consumption. This reduction results from the simple, slow-moving mechanical equipment that uses gravity drainage to dewater the biosolids. The primary disadvantages of a screw press include the potential for increased odor problems and the larger space requirements for equipment. Biosolids thickening improves energy effeciency in biosolids digestion, dewatering and disposal. The screw press produces a biosolids mass with a lower solids concentration than that from a centrifuge. The selection of a biosolids treatment method should compare the life-cycle costs of alternatives to be cost effective.
Practical Notes	When considering biosolids dewatering equipment, it is more efficient to select the smallest size equipment that will satisfy the dewatering requirements and allow for continuous operation, than to install oversized equipment that operates for only a few hours per day. This option can reduce energy consumption in two ways. In the first way, any biosolids that are held in liquid form before dewatering will need to be agitated or aerated, each requiring unnecessary energy consumption.. In the second way, smaller dewatering equipment will require smaller motors. Biosolids cake storage and transportation requirements must also be addressed prior to commencing 24-hour biosolids dewatering operations.
Other Benefits	In addition to using less energy, the screw press has lower operation and maintenance costs than a centrifuge. Furthermore, a screw press can produce Class A biosolids if modified (by adding heat).
Stage of Acceptance	Screw presses have been widely adopted for biosolids dewatering.

WW12 – Sludge: Replace Centrifuge with Gravity Belt Thickener

Best Practice	Replace centrifuge with gravity belt thickener for improved biosolids thickening.
See Also	WW11 – Biosolids: Replace Centrifuge with Screw Press
Primary Area/Process	Biosolids thickening and dewatering.
Productivity Impact	Minimal impact during installation.
Economic Benefit	Payback will depend on the size of the application.
Energy Savings	Potentially high energy savings can be achieved by this best practice.
Applications & Limitations	A gravity belt thickener consists of a gravity belt driven by a motor. As the sludge moves forward on the horizontally-moving belt, water drains through the porous belt. The biosolids are continuously turned to improve the drainage process. Biosolids thickening reduces energy consumption in biosolids digestion, dewatering and disposal. The selection of a biosolids treatment method should compare the life-cycle costs of alternatives to be cost effective.
Practical Notes	None.
Other Benefits	Other advantages associated with gravity belt thickeners include smaller space requirements than other technologies and ease of automation and control.
Stage of Acceptance	Gravity belt thickeners are widely accepted for biosolids thickening.

WW13 – Biosolids Digestion Options

Best Practice	When planning new facilities or expansion of an existing facility, assess the energy and production impacts of various biosolids processing options. Standard aerobic digestion of biosolids is energy intensive compared to fine-bubble diffusion with dissolved oxygen control and a variable air-flow rate blower. Some facilities currently turn off the air flow to the digester over extended periods of time, further reducing energy consumption. Anaerobic digestion requires detailed assessment. While the capital cost of an anaerobic digestion system is considerably greater than that of an aerobic system, an anaerobic system will consume less energy and has the potential to produce biogas for energy production over the lifetime of the system to help offset the initial capital costs of the system. Both types of system should be considered. In general, if the plant treats over 5 MGD anaerobic digestion is normally optimal and for less than 1MGD plants, aerobic digestion can be optimal. In all cases the options should be considered.
See Also	WW14 – Aerobic Digestion Options WW17 – Optimize Anaerobic Digester Performance
Primary Area/Process	This practice applies to biosolids treatment and management.
Productivity Impact	The energy impacts of recycling supernatant, for each process, should be assessed to evaluate their impacts on the treatment processes.
Economic Benefit	Payback will vary considerably from facility to facility and should be determined on a system-specific basis.
Energy Savings	Both aerobic and anaerobic systems should be considered to determine the most energy-efficient option.
Applications & Limitations	Each facility must decide the class of biosolids it wants to produce. The decision will affect the type of biosolids treatment required. Need to address if the waste being treated is a high organic (BOD) concentration irrespective of hydraulic flow this may lead to the application of anaerobic treatment to economically reduce the waste strength
Practical Notes	Operators should include all facility-specific parameters to do the assessment, particularly the amount of energy consumed and produced by each process.
Other Benefits	Each type of treatment process will affect the characteristics of the solids product, which in turn affects the solids production rates and thickening and dewatering capabilities.
Stage of Acceptance	Both aerobic and anaerobic biosolids digestion are readily available and widely accepted treatment processes.

WW14 – Aerobic Digestion Options

Best Practice	Assess your aerobic digester operation to determine if either using a separate smaller blower and/or using flexible-membrane fine-bubble diffusers and equipment with adjustable air flow rates would provide better control of airflow. Many facilities operate aerobic digesters with surface aerators or coarse-bubble diffusers that have limited ability to modify or control the amount of air flow delivered to the process. First, consider flexible membrane fine-bubble diffusers, which allow for variable air flow rates in digester applications. Second, choose equipment and/or controls with adjustable air flow rates. Often, air for the digestion process is bled from the secondary treatment process-activated sludge blowers, allowing little or no control over the air flow delivered.
See Also	WW5 – Optimize Aeration System WW6 – Fine Bubble Aeration WW7 – Variable Blower Air Flow Rate WW8 – Dissolved Oxygen Control WW13 – Biosolids Digestion Options WW15 – Biosolids Mixing Options in Aerobic Digesters
Primary Area/Process	Applies to biosolids treatment and management.
Productivity Impact	Conversion to flexible membrane fine-bubble diffuser technology and a smaller blower may improve the process of reducing volatile solids.
Economic Benefit	Payback varies with the modifications required.
Energy Savings	Application of flexible membrane fine-bubble diffusers and a separate smaller blower in an aerobic digestion system can reduce energy consumption for the process by between 20% and 50%.
Applications & Limitations	The key limitation is the final concentration of total suspended solids (TSS) in the aerobic digester. Operators may wish to be directly involved in the control of the concentration of TSS to maintain applicability of flexible membrane fine-bubble diffusers. Mixing can also be a limitation.
Practical Notes	This best practice is applicable to most systems, but will typically require that the diffusers and blowers be replaced. Some piping modifications may also be required.
Other Benefits	Fine-bubble aeration reportedly yields the following benefits: • improved biosolids dewatering; • reduced polymer demand when the digested biosolids are thickened or dewatered; • less pin floc in the biosolids processing; • improved reduction of volatile solids; • improved decanting from the digester; and • reduced volume of biosolids for disposal.
Stage of Acceptance	This technology is readily available and widely accepted except in situations where the solids concentration within the aerobic digester exceeds 2.5% total suspended solids.

WW15 – Biosolids Mixing Options in Aerobic Digesters

Best Practice	Biosolids mixing is an energy-intensive task that should be addressed in aerobic digestion. Mixing is generally provided by aeration, mechanical mixing, pumping or a combination of these methods. Aeration of the biosolids mass is required to reduce volatile solids and control odor, however, aeration may not be the most energy-efficient option for providing complete mixing in a digester, especially if constant aeration is not required. Evaluate the energy costs of available options to determine the most energy-efficient technology that fits the facility operation. A combination of mixing methods that will permit the system to be completely turned off periodically may be most practical and most energy-efficient.
See Also	WW14 – Aerobic Digestion Options
Primary Area/Process	This practice applies to all aerobic digestion systems.
Productivity Impact	No impact on productivity. A disruption should only occur during installation and start-up.
Economic Benefit	The payback period for a retrofit condition will typically range from one to three years. A new installation payback may only take one year.
Energy Savings	The potential energy savings will vary by application but can be as high as 50%.
Applications & Limitations	The limiting factor is the solids concentration in the aerobic digester.
Practical Notes	The solids concentration of the digester contents should be controlled to an approximate maximum total suspended solids concentration of 2.5%.
Other Benefits	Improved volatile solids reduction
Stage of Acceptance	Mixing technologies, including a combination of a mixing regime and an aeration methodology, are accepted by the wastewater industry.

WW16 – Biosolids Mixing Options in Anaerobic Digesters

Best Practice	The contents of an anaerobic digester must be mixed for proper operation, for the destruction of volatile suspended solids and for the production of biogas. Mixing is generally accomplished by injecting biogas into the bottom of the digester and having it pass through the contents of the tank (similar to an airlift pump). Some facilities also constantly pump the contents of the tank to continuously recirculate and mix the contents. Various mechanical mixing options can also be utilized to improve mixing and increase the level of volatile solids destruction and biogas production.
See Also	WW17 – Optimize Anaerobic Digester Performance
Primary Area/Process	This best practice applies to the complete mixing of anaerobic digesters.
Productivity Impact	Disruption in production should only occur during installation and when the biological environment evolves to make the anaerobic system function.
Economic Benefit	Payback depends on whether the system is new construction or a retrofit of an existing system. The payback for a retrofitted system will take longer.
Energy Savings	Energy savings will vary substantially depending on the specific facility conditions.
Applications & Limitations	Mixing should be employed by all anaerobic digestion systems to maximize both volatile solids destruction and biogas production.
Practical Notes	The various technologies of mixing must be evaluated to identify the best option. It is important to assess the quality of and production potential of the generated biogas and to explore its beneficial use.
Other Benefits	Maximizing the production of biogas may provide a lucrative and self-sustaining renewable energy opportunity.
Stage of Acceptance	Various mixing technologies are widely accepted throughout the industry.

WW17 – Optimize Anaerobic Digester Performance

Best Practice	Optimize anaerobic digester performance and enhance biogas production. The primary ways to optimize anaerobic digestion are: • Optimize process temperature: Changing the digester operating temperature from mesophilic (85-105°F) to thermophilic (125-140°F) increases the rate of destruction of the volatile solids in the biosolids. Two-phased anaerobic digestion and temperature-phased digestion have shown potential benefits in volatile solids reduction and biogas production enhancement. • Biosolids pre-treatment: The hydrolysis step is often the limiting factor in anaerobic digestion. Hydrolysis can be improved by pre-treatment to improve the ability of the active microorganisms to digest the biosolids. There are various pre-treatment methods available, including chemical, physical and biological methods. Three of the most promising methods include thermal treatment, ultrasonic treatment and enzyme dosing. • Co-digestion of auxiliary feedstock: It is often beneficial to co-digest biosolids with other types of organic waste, such as restaurant grease, dairy/cheese wastes, vegetable/fruit waste and municipal organic waste. By doing so, the nutrient and moisture content can be optimized, process stability can be improved and biogas production enhanced. • Pre-thickening of the biosolids being fed to the digester to reduce excess water. This will increase the residence time of volatile solids and lessen the amount of energy required to heat the biosolids fed to the digester.
See Also	WW18 – Use Biogas to Produce Heat and/or Power
Primary Area/Process	Anaerobic sludge digestion.
Productivity Impact	Minimal impact during installation of equipment.
Economic Benefit	The economic benefit of increased biogas production will be reduced by the cost of biosolids pre-treatment and biogas conditioning equipment that is necessary for biogas utilization. Acceptance of other waste may generate additional revenue for the wastewater treatment facility (WWTF).
Energy Savings	Energy savings will be proportional to the additional production of biogas for power and/or heat generation.
Applications & Limitations	None.
Practical Notes	Performance optimization of the anaerobic digester will benefit biosolids quality for downstream biosolids processing, treatment and disposal.
Other Benefits	Not applicable.
Stage of Acceptance	These optimization techniques are not widely used, but are gaining industry interest.

WW18 – Use Biogas to Produce Heat and/or Power

Best Practice	Biogas produced by an anaerobic digester can drive reciprocating engines, micro-turbines, turbines, or fuel cells to generate electricity. In addition, the thermal energy generated by these systems can often be captured and utilized to meet digester heat loads and, where applicable, for building heating. Alternatively, the biogas can be used directly as boiler fuel for the production of heat. In some limited applications biogas is even being utilized as vehicle fuel.
See Also	WW17 – Optimize Anaerobic Digester Performance
Primary Area/Process	Anaerobic sludge digestion
Productivity Impact	Minimal impact during the installation of a combined heat and power system
Economic Benefit	If sufficient biogas is available to fuel a combined heat and power (CHP) process that can generate electricity and process heat to operate the WWTF, the facility may attain energy neutrality. Whether the system generates electricity or heat, or both, the internal use of the energy will offset energy utility bills.
Energy Savings	Biogas-to-electricity generating systems need to be assessed for WWTFs that have existing anaerobic generators or are planning to install new ones. Each system needs to be individually assessed for feasibility.
Applications & Limitations	The characteristics and quality of the biogas to be utilized must be assessed on a facility-by-facility basis to determine what level of biogas conditioning (clean up) is required for the beneficial, reliable and non-harmful utilization in an engine, boiler, or process to be fueled.
Practical Notes	Reciprocating engines can be used in a majority of WWTF sizes. Micro-turbines and fuel cells are available in smaller capacity sizes for small WWTFs, where emissions are a concern. Combustion turbines can be used for WWTFs with generating capacities shown to be greater than one megawatt.
Other Benefits	Collecting and using biogas avoids venting and flaring, which release greenhouse gases. Utilization of biogas can also help a WWTF become self-sustaining.
Stage of Acceptance	Combined heat and power systems are gaining popularity in the wastewater industry.

WW19 – Cover Basins to Reduce Aerosol and Odor Emissions

Best Practice	This practice reduces, or possibly eliminates, the emissions of aerosols and odors. For tanks located in rooms where frequent air changes are required, basins can be covered to reduce the volume of fresh air required for maintenance of good indoor air quality.
See Also	Not applicable.
Primary Area/Process	This practice may be applied to any open tank treatment process including grit removal, comminution, clarification-aeration, gravity thickeners, aerobic digesters, biosolids holding tanks and disinfection tanks.
Productivity Impact	Installation of covers would interrupt the use of a tank for a limited time during installation of the cover.
Economic Benefit	Payback depends on the number and size of tanks or the size of the room where tanks are located. The payback period will increase with the amount of equipment needed to implement this practice.
Energy Savings	Energy savings is not the primary benefit of this best practice however there may be incremental savings due to a more controlled environment to control if odor becomes an item to address.
Applications & Limitations	Limitations are related to weather conditions.
Practical Notes	Many enclosure materials are available. Information on these materials can be found on manufacturers' websites.
Other Benefits	Reduced odor and improved aerosol control are the benefits from covering a structure.
Stage of Acceptance	Covering open tanks for odor or aerosol control is a widely accepted practice throughout the industry.

WW20 – Reduce Fresh Water Consumption/Final Effluent Recycling

Best Practice	Reducing the consumption of potable water through the recycling and utilization of final effluent (FE) in process applications or wash-down of tanks may save energy by limiting the volume of water treated and/or pumped. The FE system should include a pressure tank and pump control system, where appropriate and direct pumping or individual booster pump where consistently high pressure is required (belt press). Additional applications are possible with an inline filter prior to each application.
See Also	Not applicable.
Primary Area/Process	Typical applications are in the recycle system for grit washing, tank wash-down, gravity belt thickener, belt press, belt wash water, cooling water for a compressor, etc.
Productivity Impact	No impacts on production, other than minor interruptions during the installation of any required equipment.
Economic Benefit	Payback periods for this best practice are typically two to three years and will vary with the volume of potable water currently used.
Energy Savings	Savings may reach 50% of the total effluent recycle system energy if the existing system does not use a pressure tank system to regulate supply.
Applications & Limitations	Application is limited by the quality of effluent available for recycling.
Practical Notes	This best practice is usually implemented when the final effluent quality is sufficiently high that its use will not hamper the function of pumps, hoses and nozzles used in its distribution. The practice is also cost-effective when large volumes of wash water are required, such as for biosolids processing or facility wash-down.
Other Benefits	Other potential benefits associated with this measure include reducing well water consumption, reducing operation of booster pumps, where applicable and possibly eliminating the need for two water distribution systems throughout the facility.
Stage of Acceptance	Reducing the volume of potable water used in the wastewater treatment process is widely accepted throughout the industry.

WW21 – Anoxic Zone Mixing Options

Best Practice	When it becomes necessary for your wastewater treatment processes to incorporate anoxic zones, identify the best technology and methodology to mix the anoxic zone(s). Many wastewater treatment facilities (WWTFs) connect their existing aeration system blower to mix their anoxic zones. Although this method of mixing does work, other methods should be considered. For example, fractional-to-low horsepower mechanical agitators mix the anoxic zones usually at notably lower energy demands. Mechanical mixing will better manage the concentration of oxygen in the zone because it generally does not incorporate air into the contents being mixed. Also, not tapping into the aeration system enables more effective control of the aeration system.
See Also	None
Primary Area/Process	This practice applies primarily to mixing treatment tanks that are to remain anoxic.
Productivity Impact	Interruption to operation should only occur during installation of the equipment and associated controls.
Economic Benefit	Simple payback is usually in the three to five year range depending on the size of the anoxic zone(s) to be mixed.
Energy Savings	Overall savings will vary depending on the efficiency and size of the existing system to be retrofitted. Generally the reduction in energy for the anoxic mixing system ranges from 25% - 50%.
Applications & Limitations	Limitations will vary with the characteristics of the material being mixed. The higher the concentration of solids being mixed usually the greater the savings.
Practical Notes	Mechanical mixing should be assessed to account for the level of mixing required for improved process control, i.e., by limiting the entry of extraneous air bubbles into the mixing zone and disturbing the anoxic condition.
Other Benefits	Reduced air flow rate required from a blower. Also, if the air was provided by the aeration blower, one less variable for a DO control system to account for in the aeration tank, thereby improving the efficiency of the overall treatment system.
Stage of Acceptance	Anoxic zones are becoming more prevalent at WWTFs as nutrient removal limits are being required. Therefore assessing mixing options is an acceptable option.

WW22 – Biogas: Beneficial Utilization

Best Practice	Internally-generated biogas is a renewable energy resource that a WWTF should consider as a source of energy to fuel the WWTF's boilers and/or electric generation. Analysis of an anaerobic digestion biogas system requires a different view - one that looks to maximize energy production rather than to minimize energy use as with energy efficiency. The assessment should consider biogas production from initial operation all the way through to the end of its life-cycle, helping to understand the beneficial utilization over the system's lifetime. Assuming that system loads grow over the lifetime of the equipment, initial loadings will be less than design conditions. Since the capital investment of the biogas utilization system must be amortized over the design life, an analysis of the projected biogas generation must show that the life-cycle benefits outweigh the initial cost. An analysis showing how the anaerobic digester will be loaded over its lifetime should show how operation will be optimized on the overall system economics. Once the rate of biogas production has been estimated, the assessment should address options for the use of the biogas for process heat or for electric generation with heat recovery. The discovery of sufficient biogas production that can meet both the internal electric needs of the WWTF and use heat recovery to provide process heat is not unusual. The utilization of biogas for process heating has a conversion efficiency of between 80% and 85%. Conversion to electricity can be done at between 30% and 35%. If both heat and power are generated, the conversion efficiency will generally range between 70% and 75%. Both the quantity and the quality of biogas to be converted should be assessed. This assessment will determine the type and size of gas conditioning equipment that will be necessary. Many biogas systems have failed due to the improper treatment of the impurities in the biogas, resulting in poor operation and system breakdown.
See Also	WW13 – Biosolids Digestion Options WW16 – Biosolids Mixing Options Anaerobic Digesters WW17 – Optimize Anaerobic Digester Performance WW18 – Use Biogas to Produce Heat and/or Power
Primary Area/Process	Anaerobic digestion
Productivity Impact	Minimal impact that would only occur during the installation of the equipment
Economic Benefit	The economic benefit is in the opportunity to offset the WWTF's electric through the utilization of an otherwise flared-off renewable energy resource.
Energy Savings	Energy savings depend on the quantity and quality of the biogas and how much can be utilized.
Applications & Limitations	Beneficial utilization of biogas should be implemented at all WWTFs with anaerobic digestion.
Practical Notes	Biogas utilization must incorporate biogas conditioning to ensure that the system being fueled does not become impaired because of varying biogas characteristics.
Other Benefits	Beneficial utilization of biogas will assist the WWTF in moving to energy neutrality. Reduced greenhouse gas emissions.
Stage of Acceptance	Utilization of biogas is gaining in acceptance and being implemented.

WW23 – Biotower Energy Efficiency

Best Practice	Bio towers (BT) or trickling filters (TF) are engineered systems that can provide cost-effective and energy-efficient treatment of municipal and industrial wastes. They can be designed for full treatment or as an initial (roughing) treatment for high strength wastes. They are often teamed with activated sludge systems to provide tertiary treatment and/or preliminary treatment to reduce the amount of organics entering the aeration tank. The availability of PVC media has provided designers with media that has high compressive strength and identifiable void volumes so that a BT/TF can now be designed for specific treatment requirements. BT/TFs require power for pumping the influent to be treated and may include a drive to control the rotational speed of the distribution arm. Furthermore, power is consumed to recycle flows, provide flushing and meet media wetting rates. Both pumping rates and distribution arm speed must be assessed to identify the most energy-efficient pumping range for operations. These variables range from minimum media wetting rates to maximum media flushing rates, with variable influent loadings that optimize flow to wastewater organic characteristics. Assessing these variables and identifying the best balance should result in the most energy-efficient operation of a BT/TF system.
See Also	G17 – Pumps: Reduce Pumping Flow G18 – Pumps: Reduce Pumping Head G19 – Pumps: Avoid Pump Discharge Throttling
Primary Area/Process	This best practice should be applied to all bio tower and trickling filter installations.
Productivity Impact	This measure will impact operation during installation.
Economic Benefit	The estimated payback will vary with the extent of the modifications. The payback will depend on the avoided life-cycle cost of energy versus the cost of the improvement.
Energy Savings	Energy savings can vary greatly, however savings in the range of 15 to 30% of the present BT/TF energy consumption is unreasonable.
Applications & Limitations	Application of this practice is usually limited to the BT/TF feed and recycle pumps and the value of installing a drive on the distribution arm.
Practical Notes	A detailed evaluation of the system is necessary to determine which components should be changed to provide an acceptable level of energy cost savings.
Other Benefits	Reduced pump pressure and wear. The distribution arm drive will provide better speed control of the distribution arm. Improved operational flexibility for the fixed media treatment process.
Stage of Acceptance	As the industry embraces energy cost reduction opportunities, this best practice will become more acceptable.

WW24 – Energy-Efficient Membrane Treatment Options

Best Practice	Membrane bioreactor technology (MBR) is becoming a more competitive treatment alternative when best available technology (BAT) is required to meet stringent effluent limits. Application of MBR technology can provide additional advantages including reduced solids management, reduced facility size, remote monitoring and control for remote sites and improved staging implementation. A challenge that has impacted membrane application has been energy use. Some experts have suggested that this technology can be made more energy by reducing its air scour. While this may help, greater impact on energy consumption can be achieved by giving more attention to design of the BAT. This can be accomplished by assessing and determining the best turndown capability. Such an assessment should identify the proper size of the equipment needed to energy-efficiently meet current flows and design flows; simplify the system's operation; and improve membrane selection for the best flux rate for the application. MBR technology is a viable BAT for stringent treatment requirements. However, operation flexibility and energy efficiency should be incorporated into its design.
See Also	WW1 – Operational Flexibility
Primary Area/Process	Secondary and/or tertiary treatment applications.
Productivity Impact	Installation could occur without impact on treatment.
Economic Benefit	Payback will vary depending upon application as a retrofit or a new system.
Energy Savings	Energy savings will depend on the efficiency of the current treatment system compared with the new system.
Applications & Limitations	This treatment option applies particularly well to wastewater treatment facilities (WWTFs) with a space-limited site and stringent effluent quality limits.
Practical Notes	MBR technology is becoming an acceptable option to consider because its capital cost has become more competitive compared with other options used to meet stringent treatment requirements.
Other Benefits	MBR technology applications also provide other benefits: reduced solids management costs, smaller building requirements and adaptability to phased implementation.
Stage of Acceptance	Membrane technology is an acceptable treatment option that is gaining acceptance as treatment requirements become more stringent.

WW25 – Blower Technology Options

Best Practice	Blower technology is continually evolving, providing more energy-efficient options to select from. This continuous evolution in blowers needs to be continually researched and monitored to identify the most energy-efficient technology for the application being assessed. Current research and development has brought turbo blowers and new technology screw blowers to be available to WW facilities. This technology along with single stage variable vane blowers provides options to the designers of WWTFs. The value available through the evolving technology is they are more energy-efficient and operate energy-efficiently over a wider range of air flow rates. Blower technology selected for a specific application should utilize this beneficial capability of operating more energy-efficiently over a wider range of air flow rates so the selection is energy-efficient from start up through design and can be integrated with other energy-efficient attributes to make the entire WWTF energy-efficient.
See Also	WW5 – Optimize Aeration System WW6 – Fine-Bubble Aeration WW7 – Variable Blower Air Flow Rate WW8 – Dissolved Oxygen Control
Primary Area/Process	This best practice applies to all aeration applications including: aerated grit, activated sludge aeration tanks, aerobic digestion tanks, post aeration tanks and air assisted final filter backwash applications.
Productivity Impact	Interruption in treatment should only occur during installation.
Economic Benefit	Economic benefits vary from new facilities to retrofit applications. Payback on a new application may be as short as a year. Payback on a retrofit application will depend on the inefficiency of the existing operation.
Energy Savings	Energy savings will depend on the specifics of the opportunity but generally has been in the range of 15% - 25% based on improved blower energy efficiency only.
Applications & Limitations	This best practice is applied wherever blowers are installed.
Practical Notes	New technology blowers should be assessed for any existing or new design application. The new technology blowers are simply more energy-efficient and have an expanded operating range when compared to former technologies at the same air flow rate and pressure conditions.
Other Benefits	When new technology blowers are integrated with other energy-efficient modifications, fine bubble diffusers and dissolved oxygen control, effluent quality may be improved and the overall WWTF may have additional treatment capability.
Stage of Acceptance	Application of new technology blowers has gained an increasing level of acceptance.

BUILDINGS BEST PRACTICES

Checklist for Buildings Best Practices

Best Practice Analyzed? (Date)	Further Review Needed? (Yes/No)	Best Practice Possible? (Yes/No)	#	Best Practice	Typical Energy Savings of Unit Process (%)	Typical Payback (years)
			1	Install VFD Control on Air Compressors	Variable	Variable
			2	Install High-Efficiency Lighting and Advanced Controls	10 – 30	< 4
			3	Clean Lamps and Fixtures	Variable	Variable
			4	Monitor Light Operation	15 - 90	Variable
			5	Check Outside Air Ventilation Devices, Ventilation/Supply Fans and Clean Fan Blades	Variable	Variable
			6	Replace Ventilation Air Filters	Variable	Variable
			7	LEED Energy Practice	Variable	Variable
			8	Install Efficient HVAC	Variable	Variable

NOTES:

B1 – Install VFD Control on Air Compressors

Best Practice	Compressors produce low volumes of air at 80 to 140 psi. Most air compressors are rotary screw-type and are typically operated in an inlet modulation with unloading mode. In this control scheme, the air compressor produces compressed air until a desired value is reached, at which point it begins modulating and then unloads. When it unloads, the air compressor continues rotating until the maximum pressure value is reached. The unload mode is highly inefficient because it still requires about 20% of its full electrical load. Replacing the inlet modulation with an unload mode control scheme with a VFD-controlled rotary screw air compressor saves energy, especially in part-load operation.
See Also	G12 – Electric Motors: Variable Frequency Drives Applications.
Primary Area/Process	Air compressors are often found in machine shops where they are used for various maintenance functions. They are also used to feed aeration basins and operate hydraulic drives and pumps.
Productivity Impact	Better constant pressure compressed air can be more productive, since there may be no slowdowns in air usage or possible reduction in air needed.
Economic Benefit	Payback depends on the operating hours and size of the compressor.
Energy Savings	Energy savings depend on the operating hours and size of the compressor.
Applications & Limitations	None.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Widely accepted by the industry.

B2 – Install High-Efficiency Lighting and Advanced Controls

Best Practice	Incandescent lamps can be replaced with compact fluorescent lamps (CFLs), which come in all shapes and sizes and can directly replace most incandescent lamps in most fixtures. In addition, fluorescent dimming is now available for both linear fluorescent T-8 and compact fluorescent lamps. Light Emitting Diode (LED) lighting has also become a very viable alternative to incandescent and T-12 Fluorescent lighting fixtures/lamps. The quality, reliability and cost have all increased greatly within the last three years making LED lighting an alternative that requires consideration. Outdoor lighting, warehouse lighting and indoor lighting with ceiling heights exceeding 15 feet typically use a high intensity discharge (HID) type lamp, such as mercury vapor lamps, high-pressure sodium lamps, or metal halide lamps. Mercury vapor lamps are an old and inefficient technology that should generally be replaced. If the color of the light is not an issue, then high-pressure sodium lamps can provide a very efficient source of light. Otherwise, replacing mercury vapor lamps with a new technology is almost always desirable. Pulse start metal halide, LED and high output fluorescent T8s or T5s should also be looked into since they have high efficiency and can produce significant amounts of savings. Advanced lighting controls are becoming widely available and can add to the overall efficiency of the lighting system. Advanced controls include multi-level lighting controlled by motion, ambient day light, timers or a combination of all of these. Controls should be considered with all lighting retrofit and new construction projects.
See Also	Not applicable.
Primary Area/Process	Buildings, process areas, hallways, high bay applications, offices and parking lots.
Productivity Impact	Lighting quality can have significant impacts on productivity.
Economic Benefit	Payback depends on the number and type of lights and controls being replaced and is typically less than four years.
Energy Savings	Energy savings depend on the number and type of lights being replaced, but typical lighting projects can reduce the electrical lighting energy needed by 30% or more. Efficiency improvement approaching 70% have been documented with the use of LED lighting with advance controls.
Applications & Limitations	Look for the ENERGY STAR® label and Consortium for Energy Efficiency (CEE) qualified fixtures on replacement lighting.
Practical Notes	Lighting projects usually have a short simple payback period and can often be used to help finance additional energy work.
Other Benefits	Not applicable.
Stage of Acceptance	Generally accepted.

B3 – Clean Lamps and Fixtures

Best Practice	Dirt can accumulate on lamps and fixtures, resulting in a decrease in light output ranging from 5% - 50%. Fixtures and lamps should be washed on a regular schedule using the proper cleaning solution. The frequency of cleaning depends on the amount and type of dirt in the air, whether the fixture is of the ventilated or non-ventilated type and the location of the lighting. Older style fluorescent lamps last as little as three years; therefore, it may not be necessary to clean between lamp replacements. Newer fluorescent lamps can last up to 10 years and therefore must be cleaned regularly. Most normal maintenance procedures call for lamps and fixtures to be cleaned on an annual basis but that may be difficult to accomplish with limited staff. Frequent cleaning may be required if the room is exposed to large amounts of dust and grease, if the lamps are directed upward without protection from falling dust, or if the lighting is outside. Many luminaries initially provide the same illumination level, but their ability to be economically maintained and to continue their maximum effectiveness is dependent on quality and appropriateness. Properly selected fixtures can reduce the need for cleaning or can simplify the cleaning process.
See Also	Not applicable.
Primary Area/Process	All Lighting.
Productivity Impact	Cleaner fixtures mean more lighting output and brighter spaces. Better lighting can increase productivity.
Economic Benefit	This practice can ensure that the fixtures can remain in service for the duration of their expected life, which can save capital funding for when full replacements are necessary.
Energy Savings	None.
Applications & Limitations	None.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Well accepted.

B4 – Monitor Light Operation

Best Practice	Manually switching off lights is one of the best no-cost methods of saving lighting energy. With the exception of security lights and exit signs, turn off and make staff aware of how to turn on and off, all lights and signage when daylight is sufficient or whenever they are not needed. Occupancy sensors use various detection technologies to turn off lights in unoccupied areas. Occupancy sensors can potentially be installed in conference rooms, restrooms, storage areas and other spaces prone to intermittent occupancy that have lighting that is left on. Unilaterally installing occupancy sensors without understanding of the use of the space can lead to spending unnecessary additional capital.
See Also	Not applicable.
Primary Area/Process	Areas that have intermittent or low personnel usage.
Productivity Impact	No impact.
Economic Benefit	Occupancy sensors are relatively inexpensive, with installation costs typically ranging from $50 to $150 per sensor, but can have a significant impact on energy savings.
Energy Savings	Typical energy savings from occupancy sensors range from 15% - 90%, depending on type and use of space. For example, occupancy sensors integrated with bi-level fluorescent lighting can provide substantial energy savings in hallways, stairways and warehouses.
Applications & Limitations	Limited application in high traffic areas due to excess cycling of lighting fixtures, which can decrease fixture life expectancy.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Widely accepted.

B5 – Check Outside Air Ventilation Devices, Ventilation/Supply Fans and Clean Fan Blades

Best Practice	Many ventilation systems use outside air "economizer" dampers that automatically modulate the amount of outside airflow used to condition the space. These economizers allow up to 100% outside air for "free-cooling" during moderate outdoor conditions, but restrict the outside airflow to a minimum setting when it is too cold or hot outside for beneficial use. We will rarely use this feature in Hawaii but we can use economizers in conjunction with air quality monitors to control CO_2 levels and provide for required air changes. Outside air dampers and economizer cycles can have reliability problems. If the outside air damper becomes stuck open, too much outside air may enter the system and the cooling coils can be overloaded. If it is stuck closed, then the the facility may not get the proper air changes. It is necessary to clean and lubricate the movable parts and check the actuator movement periodically to ensure proper operation and to maintain maximum system efficiency. Additionally, ventilation/supply fans require routine maintenance for optimal operation. It is necessary to lubricate bearings, adjust or change fan belts and clean fan blades on an annual basis to maximize fan efficiency.
See Also	Not applicable.
Primary Area/Process	Buildings.
Productivity Impact	No impact.
Economic Benefit	Can have significant impact on costs and provide simple, cost-effective solutions to save energy.
Energy Savings	Can be significant source for energy savings.
Applications & Limitations	The main purpose of a ventilation system in a wastewater treatment plant is to supply sufficient outside ventilation air for the dilution of odor-causing contaminants, such as hydrogen sulfide and ammonia. The discharge from the ventilation system is typically treated by vapor phase systems, including wet air scrubbing and carbon adsorption. If large amounts of air are ventilated, vapor-phase systems can also be effective at providing adequate ventilation for occupancy. The ventilation system also plays an important role in conditioning the interior space.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Well accepted.

B6 – Replace Ventilation Air Filters

Best Practice	The ventilation system removes particulates contained in outside air by way of air filters. Particulate accumulation on air filters reduces airflow and increases fan energy consumption. Air filter technology has been significantly improved; the use of modern air filters improves indoor air quality while reducing the total cost of operation if the system is using VFD technology. The cost of the filter can be significant compared to the cost of fan energy required to push air through the filter. The most common improvement is to replace two-inch pleated filters with four-inch extended service pleated filters.
See Also	Not applicable.
Primary Area/Process	Buildings.
Productivity Impact	No impact.
Economic Benefit	Energy and air quality benefits.
Energy Savings	Savings can be significant if filters are old and not allowing air through.
Applications & Limitations	None.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Widely accepted.

B7 – LEED Energy Practice

Best Practice	The Leadership in Energy and Environmental Design (LEED) Green Building Rating System is a voluntary, consensus-based national rating system for developing high-performance, sustainable buildings. LEED addresses all building types and emphasizes state-of-the-art strategies in five areas: sustainable site development, water savings, energy efficiency, materials and resources selection and indoor environmental quality. Projects typically will need energy efficiency measures in order to qualify for LEED certifications. Whether new construction or major renovation, LEED certification should be considered as a possible alternative to standard design.
See Also	Not applicable.
Primary Area/Process	Affects all areas of building construction, location and energy. LEED is a comprehensive energy approach and encompasses many measures and uses standards from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and other code sources for some of its best practices.
Productivity Impact	No impact.
Economic Benefit	Proportional to energy savings achieved.
Energy Savings	Recent studies have found that on average, LEED certified buildings are more energy-efficient than standard design buildings. The level of energy efficiency and thus the amount of savings varies greatly depending on location, orientation and other factors so due diligence is required by engineers and consultants when deciding to apply for LEED certification.
Applications & Limitations	Projects should be looked at to see if applying for LEED ratings is valuable for the project.
Practical Notes	None.
Other Benefits	Not applicable.
Stage of Acceptance	Starting to receive wide levels of acceptance.

B8 – Evaluate Existing Heating, Ventilation and Air Conditioning (HVAC) for Re-comissioning or Replacement

Best Practice	Most buildings associated with water and wastewater treatment require some type of HVAC. These systems can add to the inefficiency of the overall facility and should be inspected regularly and either re-commissioned or considered for replacement with more energy-efficient units. Re-commissioning consists of an overall evaluation and adjustment of the system to ensure it is operating properly and to design conditions. Depending on the configuration of the building and existing HVAC system, there are several options for replacement. Variable Refrigerant Flow (VRF) split systems are very energy-efficient under part load conditions as they deliver air conditioning to different areas within a building based on that area's actual cooling requirement. There are also very efficient Unitary and Roof Top Units. Even window units should be evaluated for replacement with Energy Star rated equivalent units. As a part of any energy audit, the existing HVAC system should be evaluated for possible re-commissioning or replacement.
See Also	Not applicable.
Primary Area/Process	All facilities that require HVAC.
Productivity Impact	Properly sized and selected HVAC systems that are operating as designed can provide a more energy-efficient and comfortable working environment which tends to increase productivity.
Economic Benefit	Having a properly designed and operated HVAC system can provide savings in operational, maintenance and utility costs. Simple payback will depend on the size and condition of the existing system. On average, paybacks for HVAC systems replacement projects are usually between 4-8 years.
Energy Savings	Energy savings will vary based on current condition and type of existing HVAC system. Re-commission can provide 10% - 20% energy savings.
Applications & Limitations	None.
Practical Notes	HVAC systems should be properly maintained throughout the life of the unit to ensure optimal performance and efficiency
Other Benefits	Not applicable.
Stage of Acceptance	Widely accepted.

APPENDIX A - UNDERSTANDING YOUR ELECTRIC BILL

As a municipal, industrial, or commercial electricity user, a number of items can influence the rate that is paid for electricity.

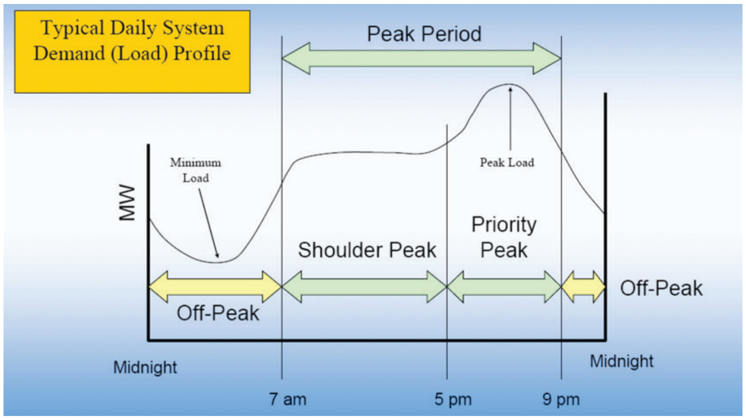
Service classification — Most water and wastewater plants in Hawaii are Schedule P.

Supply voltage — Dependent on size of equipment at the facility. Most common is 480V with 4160V for large facilities.

Rate structure — Negotiated costs per kWh use, per kW demand, how demand is charged, other fees, etc.

Usage pattern — The energy consumption load profile of the site electrical energy usage that describe the energy use such as:

- On and off-peak demand (kW)
- On and off-period energy (kWh)
- Annual peak demand (kW)
- Monthly load factor = energy usage (kWh)/ measure peak demand (kW)
- Base loads
- Variable loads



Usage Patterns for Oahu

(Neighbor islands can have different priority peak periods.)

Basic Terminology on Bill

Electricity at most facilities is billed to account for both demand and consumption.

Customer Charge Basic charge for connecting to Grid

Energy Charge Based on electricity use ($/kWh)

Demand Charge The Demand Charge is based upon the "average" power (kW) draw over a 15 minute period. This is measured four times an hour. For large facilities, the "demand load profile" may be accessed from data collected by the utility meter. Knowing when the demand peaks are occuring at your facility is critical in being able to control this cost of electricity ($/kW).

The Demand Charge also includes a "ratchet" that sets a high value in the past 11 months that is averaged with the current month's measured demand to come up with the "Billing Demand" that is charged to the customer.

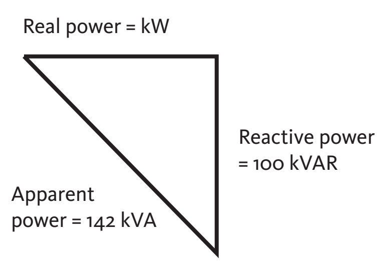
This is important to know when testing equipment as you may set an unusually high demand that you will pay for the entire year.

Rates affected: J, P, DS

Power Factor (PF) Power factor (PF) is a measure indicating the relationship of:

1. "Apparent Power" (kVa) - that the utility transformers and your switchgear are sized (kVa)
2. "Real Power" (kW) - the power that you are measured and billed for using.
3. "Reactive Power" (kVar) - the energy that is used in inductive loads that require the current to create a magnetic field for items like monitors, transformers and some types of lighting.

Hawaiian Electric Company (HECO) rates use 85% as the neutral cost point. For power factors above 85% to 100% there is a 0.1% per percent PF discount (up to 1.5% for a power factor of 100%). Conversely, there is a 0.1% per percent PF penalty for power factors below 85%. All P, DS and J rates over 200 kW have PF charges. For example, using the power triangle illustrated below, if:



Real power = kW
and
Apparent power = 142 kVA
then
Power Factor = 100/142 = 0.70 or 70%

Cost Adjustments Various costs that the Hawaii Public Utilities Commission (PUC) has authorized HECO to collect based on various market fluctuations and other factors. Usually a percentage of energy use. The largest cost adjustments are most often the "Energy Cost Adjustment" and the "Purchase Power Adjustment." Both of these charges are related to the pased through varying cost of the fuels used in the power plans. The volatility of fossil-fueled power plans in Hawaii cause this factor to be the most unpredictable driver in electrical costs.

Note that the demand charge can be billed on the maximum demand for one month or the maximum demand over the previous 12 months. It depends on the billing arrangement for specific utilities. HECO posts effective rates monthly as market conditions can affect the various charges.

For current effective rates, see HECO Effective Rates Schedule: (http://www.hawaiianelectric.com/heco/Residential/Electric-Rates/Effective-Rates-Summary-for-Hawaiian-Electric,-Maui-Electric-and-Hawaii-Electric-Light-Company).

Get To Know Your Bill

This is a sample electric bill for a wastewater treatment facility. The histogram is useful in noticing trends and establishing baselines.

NOTE: In Hawaii, temperature does not affect efficiency very much; however, rain can have an adverse effect on both water and wastewater treatment efficiency.

Hawaiian Electric Company
PO Box 3978
Honolulu, HI 96812-3978
[redacted]

Account Number: [redacted]
Invoice Number: [redacted]

Service Address Page 1 of 4
[redacted]
Contract: [redacted]

ACCOUNT SUMMARY
(See Bill Detail section for more Information)

Service Period	06/26/13 - 07/25/13	
Previous Balance	$569,203.71	
Payments	$569,203.71–	
OUTSTANDING BALANCE		**$0.00**
Current Charges	$548,184.39	
Current Charges		**$548,184.39**
TOTAL AMOUNT DUE 08/17/2013		**$548,184.39**

MESSAGES

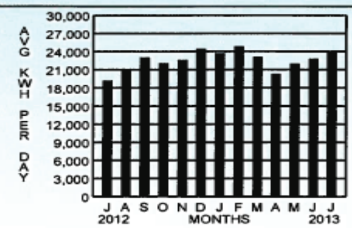
Getting hot? Learn how to stay cool and conserve energy with "Cool Tips". Check out heco.com for tips and more.

BILL PERIOD

P Large Power Service — FROM 06/26/13 TO 07/25/13 30 DAYS

METER#	REGISTER	CURRENT READING	PREVIOUS READING	DIFFERENCE	MULTIPLIER	USAGE
MPX00[redacted]	KWH	94,417.00	93,213.00	1,204.00	600	722,400.00
	KVAR	399.00	399.00	0.00	600	0.00

USAGE PROFILE



ELECTRIC USAGE PROFILE FOR METER MPX[redacted]

DATE	KWH	AMOUNT	DAYS	KWH/DAY	$/DAY
07/25/13	722400	$548,184.39	30	24,080.00	18,272.81
06/25/13	752400	$569,203.71	33	22,800.00	17,248.60
05/23/13	637800	$497,124.41	29	21,993.10	17,142.22
04/24/13	607800	$518,428.57	30	20,260.00	17,280.95
03/25/13	646800	$562,366.46	28	23,100.00	20,084.52
02/25/13	769800	$644,033.11	31	24,832.26	20,775.26
01/25/13	711000	$601,131.34	30	23,700.00	20,037.71
12/26/12	709200	$534,182.11	29	24,455.17	18,420.07
11/27/12	745800	$593,827.37	33	22,600.00	17,994.77
10/25/12	661800	$560,940.82	30	22,060.00	18,698.03
09/25/12	669000	$542,367.76	29	23,068.97	18,702.34
08/27/12	689400	$608,428.05	33	20,890.91	18,437.21
07/25/12	633600	$585,244.79	33	19,200.00	17,734.69

BILL DETAIL

DESCRIPTION	AMOUNT	TOTALS
PREVIOUS BALANCE	$569,203.71	
Incoming Payment on 07/15/2013 - Thank You	$569,203.71–	
Outstanding Balance		$0.00
CURRENT CHARGES		
Electric Service P Large Power Service		
Customer Charge	$350.00	
Demand Charge	$105,438.44	
Energy Charge	$276,538.33	
Power Factor (100)	$5,729.65–	
RBA Rate Adjustment	$24,346.24	
IRP Cost Recovery	$1,972.72	
PBF Surcharge	$7,355.77	
Energy Cost Adjustment	$100,868.92	
Purchased Power Adjustment	$36,652.05	
Renewable Infrastructure Pgm	$391.57	
Total for Current Charges		$548,184.39
Total Amount Due		$548,184.39

The Bill Detail page or screen will tell you the different charges that make up your total electric bill. Note that in this example the demand charge (kW) is almost 1/5 of the total bill. This is usually an area that can be reduced and provide substantial savings. This facility actually gets a small credit for maintaining a very high power factor. Also notice that this facility pays $7,355.77 per month into the public benefit fund (PBF surcharge on the bill). This fund pays for the energy efficiency and conservation program for ratepayers. There are also substantial adjustment charges that are a percentage of energy use so if the facility reduces energy they will also save on adjustment charges.

Put Power into the Hands of Operators and Managers

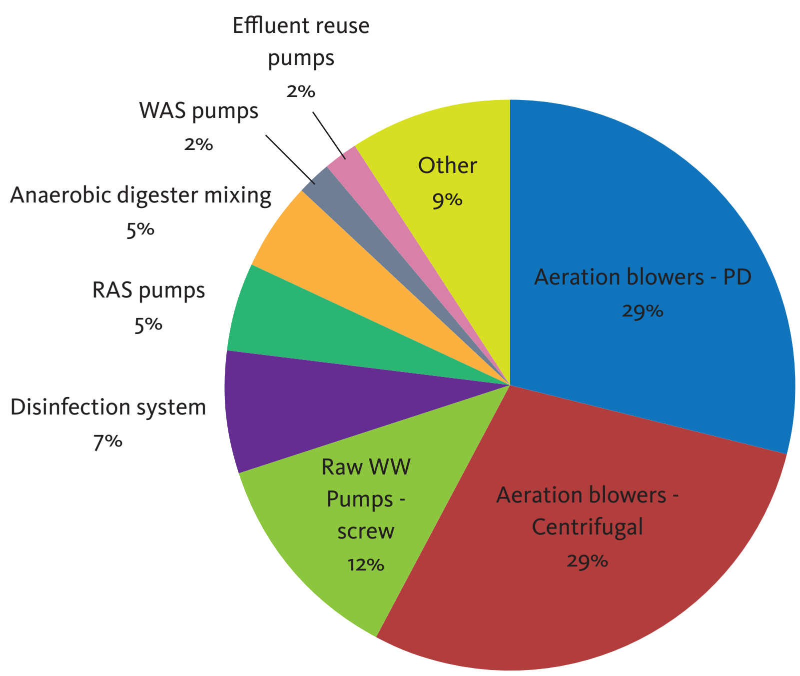
By not only allowing but insisting plant managers and operators see and understand the electric bills, water and wastewater system management can challenge the personnel that know the systems best to use their experience in reducing energy and demand charges. There are low and no-cost operational changes that can be done to lower electricity bills; turning lights off in unoccupied areas, repairing inoperative exterior lights, shifting operations to avoid or reduce monthly demand peaks are just a few things that can be done immediately.

Understanding what affects your bill is the first step to reducing it.

APPENDIX B - TYPICAL WATER/WASTEWATER TREATMENT FACILITY ENERGY DISTRIBUTION

This table and pie chart display a typical distribution of annual energy consumption broken down by type of processing equipment.

Typical Energy Consumption at WWTF							
Process or Piece of Equipment	# Units	HP of unit	kW of unit	# Units in Operation	Hrs/yr in Operation	Est. Power Consumption	% Total
Aeration blowers – PD	2	60	44.8	1	8,760	392,448	28.9%
Aeration blowers – centrifugal	2	60	44.8	1	8,760	392,448	28.9%
Raw WW pumps – screw	2	25	18.7	1	8,760	163,812	12.1%
Disinfection system	1		20	1	4,380	87,600	6.4%
RAS pumps	3	10	7.5	1	8,760	65,700	4.8%
Anaerobic digester mixing	3	20	14.9	1	4,380	65,262	4.8%
WAS pumps	3	10	7.5	1	4,380	32,850	2.4%
Effluent reuse pumps	1	10	7.5	1	4,380	32,850	2.4%
Anaerobic digester recirculation pumps	2	15	11.2	1	8,760	24,528	1.8%
Primary sludge pump	3	10	7.5	1	2.19	16,425	1.2%
Belt press	1	10	7.5	1	2,080	15,600	1.1%
Sludge transfer	2	10	7.5	1	2,080	15,600	1.1%
Grit paddle	1	2	1.5	1	8,760	13,140	1.0%
Primary clarifier	2	1	0.75	2	8,760	13,140	1.0%
Secondary clarifier	2	1	0.75	2	8,760	13,140	1.0%
Grit removal – pumps	2	5	3.7	1	2,190	8,103	0.6%
Final effluent peak pumps	3	25	18.7	1	350	6,545	0.5%
TOTAL:						1,359,191	100.0%



APPENDIX C - ECONOMIC EVALUATION METHODS

To determine whether an energy efficiency improvement project will be cost effective, most municipalities consider the "Simple Payback" (SPB) or the "Life Cycle Cost" (LCC). Typically, for smaller projects involving equipment replacement and/or low up-front capital costs, with low maintenance costs, using the SPB method is appropriate. Still, for larger projects involving significant up-front capital costs, multiple cost factors and variations in annual cash flow, LCC analysis is preferred.

Simple Payback

The SPB method calculates the length of time over which cumulative energy savings and other project benefits will be equal to (or "payback") the initial project investment. To calculate the SPB, divide the total project cost by the total expected benefit.

$$\text{SPB (years)} = \text{Cost of project (\$)} / \text{Annual savings (\$ per year)}$$

For example, assume that a facility is evaluating Project A: whether to replace its motors with more efficient models. If the new motors cost $200,000 and are expected to reduce energy costs by $100,000 per year and last for five years before another $200,000 motor replacement is needed, then the SPB for Project A is two years.

Life Cycle Cost

LCC analysis considers the initial cost of the project as well as all of the costs and benefits over the lifetime of the project. The LCC approach incorporates the time value of money, the volatility of utility costs and other factors, such as operation and maintenance or other costs.

$$LCC_{\text{Savings}} = LCC_{\text{Current process}} - LCC_{\text{New process}}$$

where :

$$LCC_{\text{Current process}} = \Sigma \text{ Annual costs} - \Sigma \text{ Annual savings}$$
$$LCC_{\text{New process}} = \text{Capital cost} + \Sigma \text{ Annual costs} - \Sigma \text{ Annual savings}$$

For example, assume the same facility is evaluating Project B: whether to use a new treatment process, which will cost $700,000 in the first year, with replacement costs of $200,000 every five years. Project B is expected to save the facility $184,000 per year for 20 years.

The SPB of this project is 3.8 years. On first look, Project A is more appealing with a SPB of two years versus nearly four years for Project B. Nevertheless, Project B will generate more savings over time. Assuming an interest rate of 7% and an escalation rate of 3%, the LCC of Project A saves $660,000 in today's dollars, whereas Project B saves $1,300,000 – a difference of $650,000.

Backup calculations for both examples are provided in the following pages. Note: the examples provided are an oversimplification provided for the purpose of showing the payback and life cycle costs calculations. The examples do not take into consideration labor and parts costs over the life of the project.

The US Environmental Protection Agency (EPA) Energy Star Tools and Resources Library (http://www.energystar.gov/index.cfm?c=tools_resources.bus_energy_management_tools_resources) provides links to various Financial Evaluation Tools, including a Cash Flow Opportunity Calculator (a Microsoft Excel-based tool) to help decision-makers to evaluate the benefits of installing energy-efficient equipment.

The US Department of Energy's Federal Energy Management Program (FEMP) offers many resources to assist with Life-Cycle Cost Analysis (http://www1.eere.energy.gov/femp/program/lifecycle.html) including FEMP's Building Life-Cycle Cost Software, training opportunities and a Life Cycle Costing Manual.

LIFE CYCLE COST EXAMPLE - PROJECT A

Interest Rate (i) = 7.0%

Escalation Rate (e) = 3.0%

Project A					
Year (n)	**Capital Cost**	**Replacement Cost**	**Annual Energy Savings**	**Total Annual Cost**	**PW Cost**
0	$200,000			$200,000	$200,000
1			- $100,000	- $100,000	- $93,458
2			- $106,090	- $106,090	- $92,663
3			- $109,273	- $109,273	- $89,199
4			- $112,551	- $112,551	- $85,865
5		$231,855	- $115,927	- $115,927	- $82,655
6			- $119,405	- $119,405	- $79,565
7			- $122,987	- $122,987	- $76,590
8			- $126,677	- $126,677	- $73,727
9			- $130,477	- $130,477	- $70,971
10		$268,783	- $134,392	- $134,392	- $68,318
11			- $138,423	- $138,423	- $65,764
12			- $142,576	- $142,576	- $63,305
13			- $146,853	- $146,853	- $60,939
14			- $151,259	- $151,259	- $58,661
15		$311,593	- $155,797	- $155,797	- $56,468
16			- $160,471	- $160,471	- $54,357
17			- $165,285	- $165,285	- $52,325
18			- $170,243	- $170,243	- $50,369
19			- $175,351	- $175,351	- $48,486
20		$316,222	- $180,611	- $180,611	- $46,673
					- $662,130

Future Annual Cost = Present Annual Cost × (1 + Escalation Rate)^{Year} = $A_o(1+e)^n$

Present Worth Cost = PW = Future Annual Cost / (1 + Interest Rate)^{Year} = $F/(1+i)^n$

LIFE CYCLE COST EXAMPLE - PROJECT B

Interest Rate (i) = 7.0%

Escalation Rate (e) = 3.0%

Project B					
Year (n)	Capital Cost	Replacement Cost	Annual Energy Savings	Total Annual Cost	PW Cost
0	$700,000			$700,000	$700,000
1			-$184,000	-$184,000	-$171,963
2			-$195,206	-$195,206	-$170,500
3			-$201,062	-$201,062	-$164,126
4			-$207,094	-$207,094	-$157,991
5		$231,855	-$213,306	$18,549	$13,225
6			-$219,706	-$219,706	-$146,399
7			-$226,297	-$226,297	-$140,926
8			-$233,086	-$233,086	-$135,658
9			-$240,078	-$240,078	-$130,587
10		$268,783	-$247,281	$21,502	$10,931
11			-$254,699	-$254,699	-$121,006
12			-$262,340	-$262,340	-$116,482
13			-$270,210	-$270,210	-$112,128
14			-$278,317	-$278,317	-$107,936
15		$311,593	-$286,666	$24,927	$9,035
16			-$295,266	-$295,266	-$100,017
17			-$304,124	-$304,124	-$96,278
18			-$313,248	-$313,248	-$92,679
19			-$322,645	-$322,645	-$89,214
20		$361,222	-$332,324	$28,898	$7,468
					-$1,313,231

Future Annual Cost = Present Annual Cost × (1 + Escalation Rate)^{Year} = $A_o(1+e)^n$

Present Worth Cost = PW = Future Annual Cost / (1 + Interest Rate)^{Year} = $F/(1+i)^n$

ADDITIONAL RESOURCES

Water and Wastewater Energy Best Practice Guidebook
Provided by Focus on Energy, prepared by Science Applications International Corporation (SAIC), 2006

"Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities", U.S. Environmental Protection Agency, 2008

State of Hawaii Annual Public Water System Compliance Report, 2010

"Water Resource Protection Plan (WRPP)", State of Hawaii Commission on Water Resource Management, 2008

Hawaii Energy
http://www.hawaiienergy.com

New York State Energy Research and Development Authority (NYSERDA) Focus on Water and Wastewater
http://water.nyserda.org

U.S. Environmental Protection Agency's ENERGY STAR® Portfolio Manager Platform
http://www.energystar.gov/index.cfm?c=eligibility.bus_portfoliomanager_eligibility

U.S. Department of Energy
http://www1.eere.energy.gov/industry/bestpractices/software.html

U.S. Green Building Council
http://www.usgbc.org

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
http://www.ashrae.org